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Volume 4. Case Study Examples

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→ This document, ~~which is~~ presented in four volumes, provides guidance to the owner or operator of hazardous waste management facilities as to the conduct of the second phase of the RCRA Corrective Action Program, the RCRA Facility Investigation (RFI). This document, Volume IV of the RCRA Facility Investigation Guidance contains case studies selected to illustrate various concepts and procedures in Volumes I, II, and III. These case studies are provided to explain, through example, how various tasks can be conducted during RFIs. The case studies also identify some of the potential problems that can occur if the RFI sampling and analytical problems are not carefully designed and executed. The case studies, however, should not be used as the primary source of guidance for RFI program design and conduct. Volumes I, II and III should be consulted. Most of the case studies are based on actual sites. In some cases, existing data have been supplemented with hypothetical data to illustrate a particular point. ←

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VOLUME IV OF IV

CASE STUDY EXAMPLES

EPA 530/SW-87-001D

JULY 1987

DRAFT

WASTE MANAGEMENT DIVISION
OFFICE OF SOLID WASTE
U.S. ENVIRONMENTAL PROTECTION AGENCY

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ABSTRACT

On November 8, 1984, Congress enacted the Hazardous and Solid Waste Amendments (HSWA) to RCRA. Among the most significant provisions of HSWA are §3004(u), which requires corrective action for releases of hazardous waste or constituents from solid waste management units at hazardous waste treatment, storage and disposal facilities seeking final RCRA permits; and §3004(v), which compels corrective action for releases that have migrated beyond the facility property boundary. EPA will be promulgating rules to implement the corrective action provisions of HSWA, including requirements for release investigations and corrective measures.

This document, which is presented in four volumes, provides guidance to the owner or operator of hazardous waste management facilities as to the conduct of the second phase of the RCRA Corrective Action Program, the RCRA Facility Investigation (RFI). Instruction is provided for the development and performance of an investigation based on determinations made by the regulatory agency as expressed in the schedule of a permit or in an enforcement order issued under HSWA§3008(h). The purpose of the RFI is to obtain information to fully characterize the nature and extent of releases of hazardous waste or constituents. This information will be used to determine whether interim corrective measures or a Corrective Measures Study will be necessary.

DISCLAIMER

This Draft Report was prepared for the U.S. Environmental Protection Agency by the NUS Corporation, Waste Management Services Group, Gaithersburg, MD 20878, in fulfillment of Contract No. 68-01-7310, Work Assignment No. 5, and is based on previous work performed by Alliance Technologies, Inc., under Contract No. 68-01-6871. The opinions, findings, and conclusions expressed herein are those of the authors and not necessarily those of the U.S. Environmental Protection Agency or the cooperating agencies. Mention of company or product names is not to be considered an endorsement by the U.S. Environmental Protection Agency.

This document is intended to assist Regional and State personnel in exercising the discretion conferred by regulation in developing requirements for the conduct of RCRA Facility Investigations (RFIs) pursuant to 40 CFR 264. Conformance with this guidance is expected to result in the development of RFIs that meet the regulatory standard of adequately detecting and characterizing the nature and extent of releases. However, EPA will not necessarily limit acceptable RFIs to those that comport with the guidance set forth herein. This document is not a regulation (i.e., it does not establish a standard of conduct which has the force of law) and should not be used as such. Regional and State personnel must exercise their discretion in using this guidance document as well as other relevant information in determining whether an RFI meets the regulatory standard.

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RCRA FACILITY INVESTIATION (RFI) GUIDANCE

VOLUME IV

CASE STUDY EXAMPLES

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LIST OF ACRONYMS

AA - Atomic Absorption
AI - Soil Adsorption Isotherm Test
ASCS - Agricultural Stabilization and Conservation Service
ASTM - American Society for Testing and Materials
BCF - Bioconcentration Factor
BOD - Biological Oxygen Demand
CAG - EPA Carcinogen Assessment Group
CPF - Carcinogen Potency Factor
CBI - Confidential Business Information
CEC - Cation Exchange Capacity
CERCLA - Comprehensive Environmental Response, Compensation, and Lability Act
CFR - Code of Federal Regulations
CIR - Color Infrared
CM - Corrective Measures
CMI - Corrective Measures Implementation
CMS - Corrective Measures Study
COD - Chemical Oxygen Demand
COLIWASA - Composite Liquid Waste Sampler
DNPH - Dinitrophenyl Hydrazine
DO - Dissolved Oxygen
DOT - Department of Transportation
ECD - Electron Capture Detector
EM - Electromagnetic
EP - Extraction Procedure
EPA - Environmental Protection Agency
FEMA - Federal Emergency Management Agency
FID - Flame Ionization Detector
Foc - Fraction organic carbon in soil
FWS - U.S. Fish and Wildlife Service
GC - Gas Chromatography
GC/MS - Gas Chromatography/Mass Spectroscopy
GPR - Ground Penetrating Radar
HEA - Health and Environmental Assessment
HEEP - Health and Environmental Effects Profile
HPLC - High Pressure Liquid Chromatography
HSWA - Hazardous and Solid Waste Amendments (to RCRA)
HWM - Hazardous Waste Management
ICP - Inductively Coupled (Argon) Plasma
ID - Infrared Detector
Kd - Soil/Water Partition Coefficient
Koc - Organic Carbon Absorption Coefficient
Kow - Octanol/Water Partition Coefficient
LEL - Lower Explosive Limit
MCL - Maximum Contaminant Level
MM5 - Modified Method 5
MS/MS - Mass Spectroscopy/Mass Spectroscopy
NFIP - National Flood Insurance Program
NIOSH - National Institute for Occupational Safety and Health
NPDES - National Pollutant Discharge Elimination System
OSHA - Occupational Safety and Health Administration

LIST OF ACRONYMS (Continued)

OVA - Organic Vapor Analyzer
PID - Photo Ionization Detector
pKa - Acid Dissociation Constant
ppb - parts per billion
ppm - parts per million
PUF - Polyurethane Foam
PVC - Polyvinyl Chloride
QA/QC - Quality Assurance/Quality Control
RCRA - Resource Conservation and Recovery Act
RFA - RCRA Facility Assessment
RfD - Reference Dose
RFI - RCRA Facility Investigation
RMCL - Recommended Maximum Contaminant Level
RSD - Risk Specific Dose
SASS - Source Assessment Sampling System
SCBA - Self Contained Breathing Apparatus
SCS - Soil Conservation Service
SOP - Standard Operating Procedure
SWMU - Solid Waste Management Unit
TCLP - Toxicity Characteristic Leaching Procedure
TEGD - Technical Enforcement Guidance Document (EPA, 1986)
TOC - Total Organic Carbon
TOT - Time of travel
TOX - Total Organic Halogen
USGS - United States Geologic Survey
USLE - Universal Soil Loss Equation
UV - Ultraviolet
VOST - Volatile Organic Sampling Train
VSP - Verticle Seismic Profiling
WQC - Water Quality Criteria

14.0 INTRODUCTION

14.1 Use of Case Studies

This document, Volume IV of the RCRA Facility Investigation (RFI) Guidance, contains case studies selected to illustrate various concepts and procedures in Volumes I, II, and III. These case studies are provided to explain, through example, how various tasks can be conducted during RFIs. The case studies also identify some of the potential problems that can occur if the RFI sampling and analytical programs are not carefully designed and executed. The case studies, however, should not be used as the primary source of guidance for RFI program design and conduct. Instead, Volumes I, II and III should be consulted. The studies do not necessarily address details specific to individual facilities, and omission of certain RFI tasks should not be interpreted as an indication that such tasks are unnecessary or of less significance. Most of the case studies are based on actual sites. In some cases, existing data have been supplemented with hypothetical data to illustrate a particular point.

14.2 Organization of Volume IV

Table 14-1 lists the points illustrated and identifies the case studies which provide information relevant to these points. The following general form was used as appropriate for each case study:

- Title
- Identification of Points Illustrated
- Introduction/Background
- Facility Description
- Program Design/Data Collection
- Program Results/Data Analysis
- Case Discussion

TABLE 14-1

SUMMARY OF POINTS ILLUSTRATED

POINTS ILLUSTRATED	CASE STUDY NUMBER
SOIL	
• Use of soil characteristics to estimate mobility of contaminants in soil	1
• Effects of degradation in determining the fate of a contaminant in soil	2
GROUNDWATER	
• Use of split-spoon sampling and organic vapor monitoring to select screened intervals for ground water monitoring	3
• Development of a two-phase boring program to investigate ground water contamination	4
• Use of basement monitoring to estimate contaminant migration	5
• Use of mathematical models to determine locations of ground water monitoring wells	6
• Monitoring and characterization of ground water contamination when two liquid phases are present	7
• Methodology for construction of vertical flow nets	28
SUBSURFACE GAS	8
• Design of a phased monitoring program to adequately characterize subsurface gas migration	9
• Use of predictive models to estimate extent of subsurface gas migration	
SURFACE WATER	
• Use of existing site-specific data to design a surface water monitoring program	10
• Use of bioassays and bioaccumulation studies to assess potential biological effects of off-site contaminant migration	11
• Use of sediment sampling to indicate off-site contaminant migration via surface runoff	12
• Design of a sampling program to account for three-dimensional variations in contaminant distribution	13
• Use of dispersion zone concepts in the design of a surface water monitoring program	29
AIR	
• Use of dispersion modeling and air monitoring data to estimate downwind contaminant concentrations	14
• Design of an upwind/downwind monitoring program when multiple sources are involved	15
SELECTION OF MONITORING CONSTITUENTS	
• Use of 40 CFR Part 261 Listing Background Documents in selecting monitoring constituents	16
• Consideration of degradation as a factor in identifying monitoring constituents	2

TABLE 14-1
SUMMARY OF POINTS ILLUSTRATED
PAGE TWO

POINTS ILLUSTRATED	CASE STUDY NUMBER
SAMPLING SCHEMES	
• Selection of a sampling scheme that appropriately characterizes soil contamination	17
• Evaluation of the effectiveness of a sampling scheme using statistical analyses	17
• Use of release monitoring/leachate collection to characterize wastes when the actual waste stream is inaccessible, as in the case of buried drums	18
WASTE CHARACTERIZATION	
• Correlation of a contaminant release with a specific waste management unit using ground water data	19
• Use of site topographic information in selecting test boring and monitoring well locations at facilties where large volumes of waste have been disposed	20
• Use of waste stream information to select indicator parameters and monitoring constituents in a ground water monitoring program and to reduce the number of Appendix VIII constituents that must be monitored	21
• Use of information on possible waste reaction products in designing a ground water monitoirng program	22
AERIAL PHOTOGRAPHY	
• Use of aerial photographs to identify actual and potential waste migration routes and areas requiring corrective action	23
• Identification of a ground water contaminant plume using infrared aerial photography	24
• Use of historical aerial photographs and facility maps to identify old waste disposal areas and ground-water flow paths	31
DATA PRESENTATION	
• Techniques for presenting data for facility investigation involving multimedia contamination	25
QUALITY ASSURANCE AND CONTROL	
• Use of quality assurance and control and data validation procedures	26
HEALTH AND SAFETY	
• Example of a health and safety plan	30
CORRECTIVE MEASURES INCLUDING INTERIM MEASURES	
• Use of biodegradation and removal for interim corrective measures	2
• Corrective action and the implementation of interim corrective measures	27

15.0 CASE STUDIES

CASE STUDY 1: USING SOIL CHARACTERISTICS TO ESTIMATE MOBILITY OF CONTAMINANTS

Point Illustrated

- Information on soil characteristics can be used to estimate the relative mobility of contaminants in the subsurface environment.

Introduction

The relative mobility of contaminants can be estimated using soil characteristics and aquifer hydraulic characteristics. Although metals do precipitate at higher concentrations, at the levels encountered in most subsurface environments, sorption is the dominant attenuation process. The degree to which a metal sorbs onto soil particles depends on the soil pH, the percent clay, the percent soil organic matter, the presence of particular coatings (e.g., iron, manganese, and aluminum oxide/hydroxides) and to a lesser extent, the type of clay present. For organic contaminants, there are several processes which may be important in predicting their fate in soils. These include sorption, biodegradation, hydrolysis and, to a lesser extent, volatilization. The sorption of a given organic compound can be predicted based on its octanol-water partition coefficient, the percent organic carbon in the soil, and the grain-size distribution of the soil.

Determining the relative mobility of contaminants can be helpful in selecting appropriate sampling locations. For example, if wastes containing metals were present in an impoundment, samples to determine the extent of any downgradient metal contamination would normally be collected within a short distance of the impoundment. On the other hand, for fairly mobile waste constituents such as trichloroethylene (TCE), samples could be taken over a much larger downgradient distance. The case study presented below illustrates how contaminant mobility can be estimated.

Facility Description

A 17 acre toxic waste dump operated in a mountain canyon for 16 years. The facility received over 32 million gallons of spent acids and caustics in liquid form. These wastes were placed in evaporation ponds. Other wastes sent to the facility included solvents and wastes from electroplating operations containing chromium, lead, mercury and zinc. Pesticides including DDT had been disposed of in one corner of the site.

Site Description

The site was underlain by alluvium and granitic bedrock (Figure 15-1). The bedrock, as it was later discovered, was fractured to depths of between 50 and 100 feet. Ground water occurred in the alluvial deposits at depths of 10 to 30 feet. Several springs existed in the upgradient portion of the site. A barrier dam was built across part of the canyon at the downgradient edge of the site in an effort to control leakage. Because of the extensive fracture system, this barrier was not effective. Instead, it appears to have brought the ground water table up into the wastes, and at the same time, pressurized the underlying fracture system, thereby creating seepage of contaminated water under the dam.

Estimation of Contaminant Mobility

Because of the variety of constituents accepted at this site, an estimate of their relative mobility was needed prior to designing the remedial investigation. The first step was to estimate the downgradient seepage velocity using the following equation:

$$V_S = \frac{KI}{P}$$

where

V_S = horizaontal seepage velocity, ft/day

K = hydraulic conductivity, ft/day

I = ground water gradient

P = effective porosity, decimal fraction.

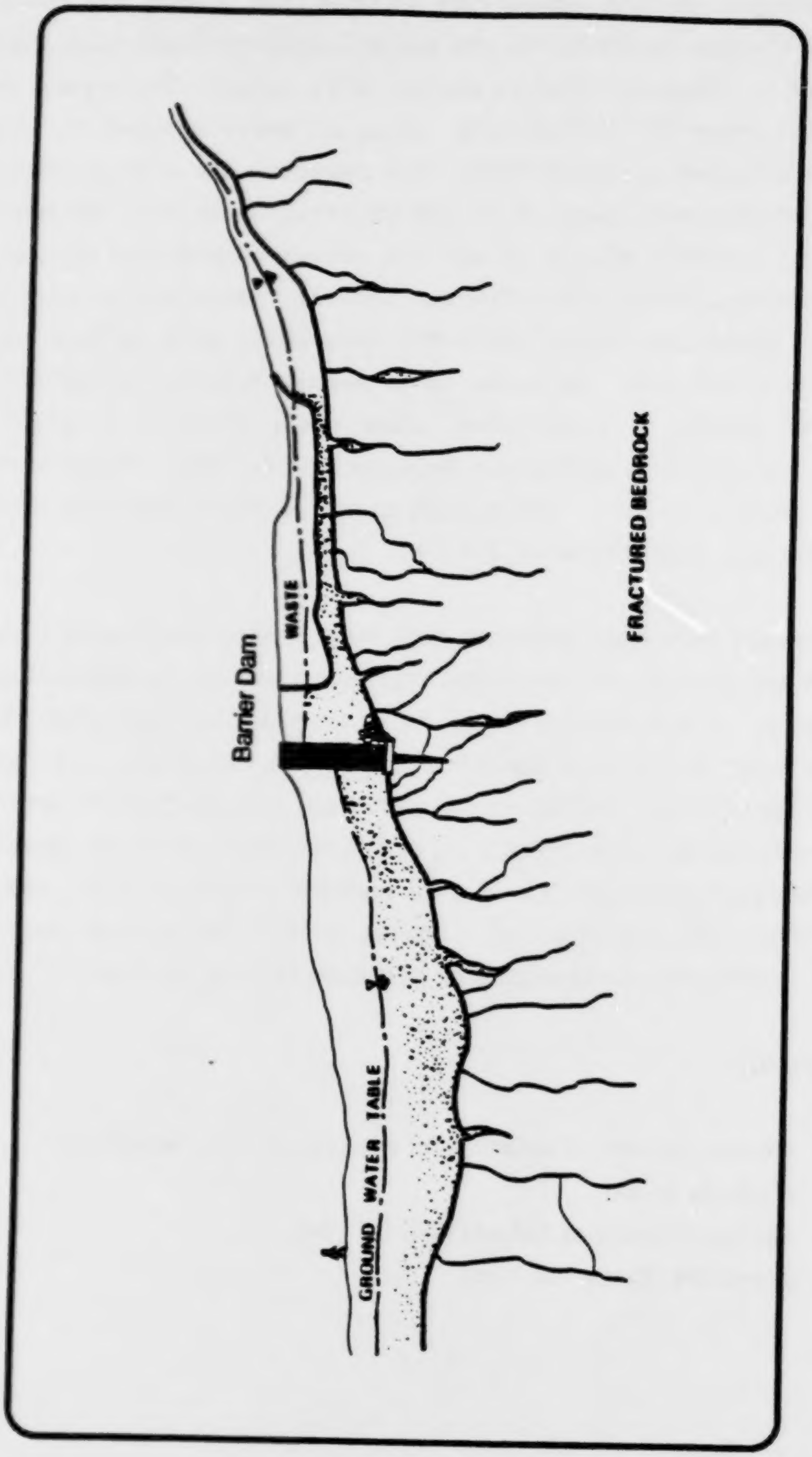

Barrier Dam
WASTE
GROUND WATER TABLE
FRACTURED BEDROCK

Figure 15-1. Schematic Cross-Section of Waste Disposal Site

The hydrogeologic data needed were obtained from existing site assessment reports. The alluvium underlying the site had an average hydraulic conductivity of [illegible].8 ft/day and an estimated effective porosity of 11 percent. The average ground water gradient below the site was 0.06. Using the above equation, the seepage velocity was estimated to be 160 ft/yr. This represents the average velocity at which a conservative constituent would migrate downgradient along the centerline of the plume. Examples of such constituents include chloride and bromide. As shown in Table 15-1, nitrate and sulfate also behave conservatively in many cases. Due to the absence of highly weathered, sesquioxide soils, sulfate behaved conservatively at this site. Using the above seepage velocity, an estimate was made of the distance a conservative solute would travel in a given time, T ($d = V_S T$). Limited water quality data were available for 1980. Wastes were first disposed at this site in 1956. The average extent of plume migration along the centerline was thus estimated to be 3800 feet.

With respect to metals, additional data were needed to estimate their fate including soil pH, presence of carbonates, organic ligands, and percent soil organic matter and clay. At this site, the soil pH varied from less than 3.0 within 400 feet of the acid ponds to 7.2 at a distance 2000 feet downgradient. As shown in Figure 15-2, the partition coefficients for metals are dependent on pH and organic matter content. For example, below a pH of 5.6, for the types of soil encountered at the site, the partition coefficient (K_p) for cadmium is about 10 ml/g. At a pH of 7.2, K_p is about 6500 ml/g (Rai and Zachara, 1985). The relative mobility of attentuated constituents can be estimated as follows (Mills et al., 1985):

$$V_A = V_S / R_d$$

where

V_A = average velocity of attentuated consitutent along centerline of plume, ft/day

V_S = seepage velocity as defined above, ft/day

R_d = retardation factor (unitless)

and

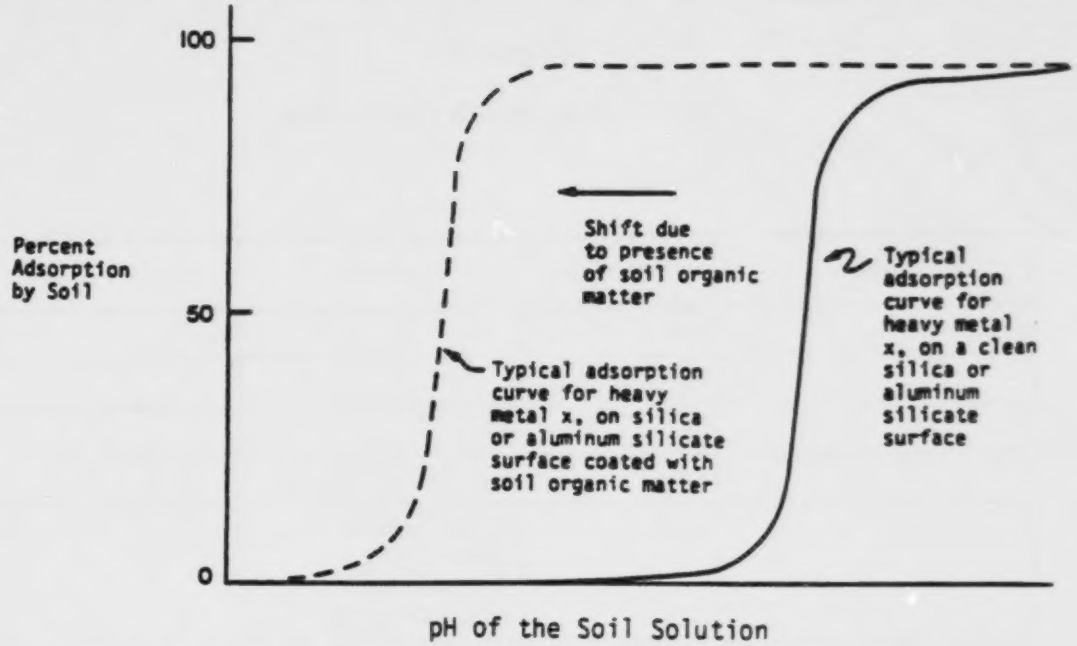
$$R_d = 1 + \frac{K_p \rho_B}{p}$$

TABLE 15-1

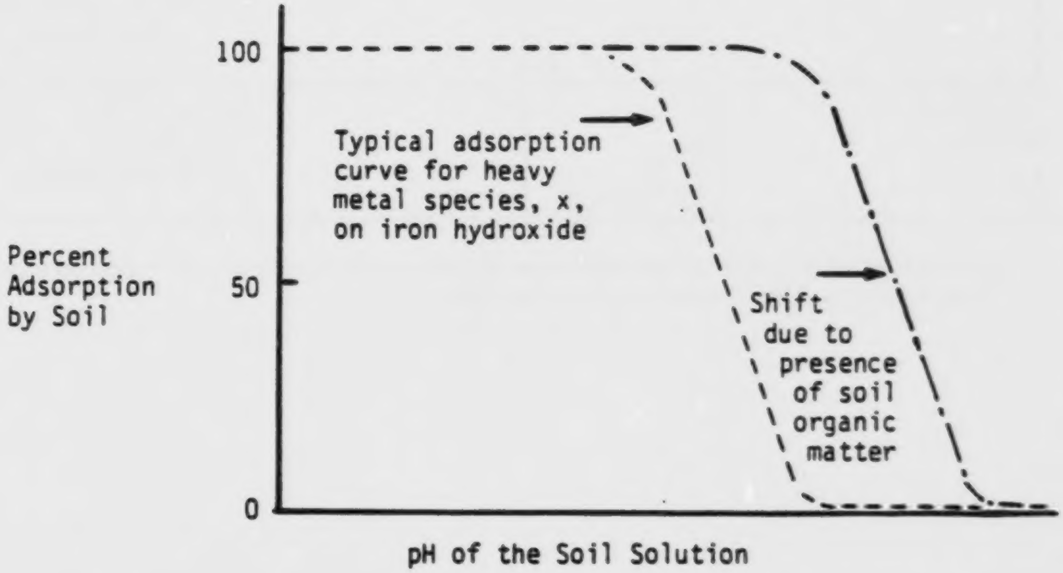
RELATIVE MOBILITY OF SOLUTES

Group	Examples	Exceptions	Master Variables*
Conservative	TDS		V_s
	CL^-		
	BR^-		
	NO_3^-	Reducing conditions	
	SO_4^{2-}	Reducing conditions and in highly weathered soils coated with sesquioxides	
Slightly Attenuated	B	Strongly acidic systems	V_s, pH, organic matter
	TCE	Anaerobic conditions	V_s, organic matter
Moderately Attenuated	Se		V_s, pH, Fe hydroxides,
	As		V_s, pH, Fe hydroxides,
	Benzene		V_s, organic matter
More Strongly Attenuated	Pb		V_s, pH, SO_4^{2-}
	Hg		V_s, pH, $C1^-$
	Pentachlorophenol		V_s, organic matter

* Variables which strongly influence the fate of the indicated solute groups. Based on data from Mills et al., 1985 and Rai and Zachara, 1984.



a) Generalized Heavy Metal Adsorption Curve for Cationic Species (e.g., $CuOH^+$)



b) Generalized Heavy Metal Adsorption Curve for Anionic Species (e.g., CrO_4^{2-})

Figure 15-2. **Hypothetical Adsorption Curves for a) Cations and b) Anions Showing Effect of pH and Organic Matter (Mills et al., 1985)**

where

K_p = soil-water partition coefficient for solute of concern, ml/g

ρ_B = soil bulk density, g/ml

p = effective soil porosity (decimal fraction).

For example, the relative mobility of cadmium at a pH of 7.2 was computed for this site as shown below:

$$R_d = 1 + \frac{6500(1.7)}{0.11} = 100,000$$

$$V_A = 160/100,000 = 0.002 \text{ ft/yr.}$$

This estimate was consistent with the field data which indicated that the metals migrated only until the pH of the contaminated plume was neutralized, a distance of about 2000 feet. Cadmium concentrations decreased from 1.3 mg/l at a distance of 1400 feet from the ponds to below detection (0.1 μg/l) at a distance of 2000 feet.

Estimates of mobility for organic contaminants which sorb onto soil particles can be made in an analogous manner. The partition coefficient for organic constitutents can be calculated using the following equation (Mills et al., 1985):

$$K_p = K_{oc}[0.2(1-f)X^s_{oc} + fX^f_{oc}]$$

where

K_p = soil-water partition coefficient, ml/g

K_{oc} = organic carbon partition coefficient, ml/g

and

$K_{oc} = 0.63\ K_{ow}$

K_{ow} = octanol-water partition coefficient

$$f = \frac{\text{mass of silt and clay}}{\text{mass of silt, clay and sand}} \quad (0 \leq f \leq 1)$$

X^s_{oc} = organic fraction of sand ($X^s_{oc} \leq 0.01$)

X^f_{oc} = organic fraction of silt-clay ($0 \leq X^f_{oc} \leq 0.1$)

For example, the solvent trichlorethylene (TCE) has a K_{ow} value of 200. Using the above equation and site data ($f = 0.1$, $X_{oc}^{s} = 0.001$, $X_{oc}^{f} = 0.01$), the partition coefficient K_p was estimated to be 0.2 ml/g. The relative mobility of TCE at the site was then estimated as shown above ($R_d = 4$ and $V_A = 40$ ft/yr). Methods for considering additional processes influencing the fate of organics (e.g., hydrolysis and biodegradation) are presented in the manual entitled "Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants in Surface and Ground Water" (Mills *et al.*, 1985). This document has been designated "National Guidance" by the U.S. Environmental Protection Agency.

Case Discussion

As shown in Figure 15-3, contaminants downgradient of a waste disposal site migrate at different speeds. Using the methods illustrated above, estimates of the relative mobility of constituents can be made. Such estimates can then be used to locate downgradient monitoring wells and to assist in the interpretation of field data.

References

Mills, W.B., D.B. Porcella, M.J. Ungs, S.A. Gherini, K.V. Summers, L. Mok, G.L. Rupp, and G.L. Bowie. 1985. Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants in Surface and Ground Water. EPA/600/6-85/002a, Vol. I, II and III.

Rai, D. and J.M. Zachara. 1984. Chemical Attenuation Studies: Data Development and Use. Presented at Second Technology Transfer Seminar: Solute Migration in Ground Water at Utility Waste disposal Sites. Held in Denver, Colorado, October 24-25, 1985. 63 pp.

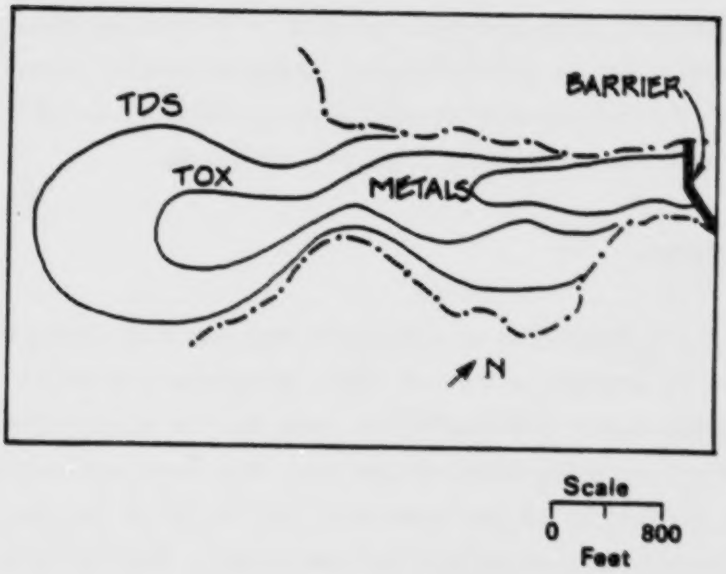

TDS
TOX
METALS
BARRIER
N
Scale
0
800
Feet

Figure 15-3. Schematic Diagram Showing Plumes of Total Dissolved Solids (TDS), Total Organic Halogens (TOX) and Heavy Metals Downgradient of Waste Disposal Site

CASE STUDY 2: ESTIMATION OF DEGRADATION POTENTIAL OF CONTAMINANTS IN SOIL

Point Illustrated

- Degradation, either chemical or biological, can be an important factor in determining the fate of a contaminant in soil, and can also be a factor in identifying constituents to monitor for. The degradation rate can also be accelerated as a means of conducting interim or definitive corrective measures.

Introduction

Degradation of contaminants in the environment can occur through several mechanisms, and can be a factor in identifying monitoring constituents. Under natural conditions, these processes are often very slow, but studies have shown that chemical and biological degradation can be accelerated in the soil by modifying soil conditions. Parameters such as soil moisture content and redox condition can be altered to encourage contaminant degradation in soils.

Site Description

The site is situated in an arid region that was used during the 1970s by aerial applicators of organochlorine and organophosphate pesticides. The applicators abandoned the site in 1980 and homes were built in the vicinity. The site can be divided into three areas based on past use. The most contaminated area, the hot zone, is a 125 feet by 50 feet area at the north end of the site that was used for mixing, loading, and unloading the pesticides. Soil samples from this area contained toxaphene, ethyl parathion, and methyl parathion at concentrations up to 15,000 mg/kg, and were clearly above health and environmental criteria. The present residential area was used as a taxiway and an area to rinse tanks and clean planes. Soils from this zone were low in parathions but toxaphene concentrations ranging from 20 to 700 mg/kg were found, and in some cases exceeded health and environmental criteria. This area is approximately 1.7 acres in size and located immediately south and west of the hot zone. The runway itself was approximately 10 acres in size and to the south of the residential zone. Soil sample results from the runway area were low for all three pesticides.

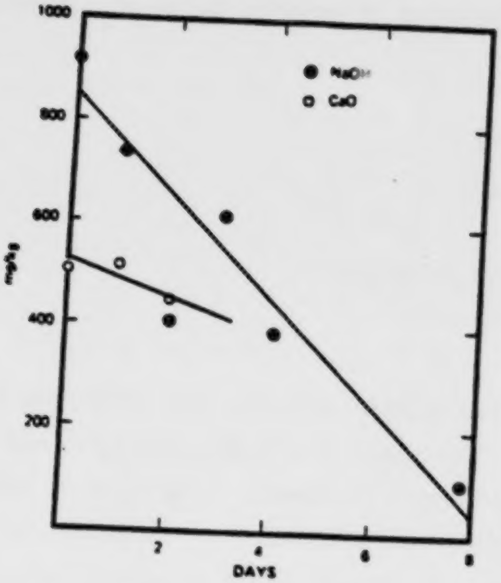
A number of factors influence degradation of organic compounds in soils. These include:

- chemical nature of the compound
- organic matter content of the soil
- soil pH
- oxidation/reduction environment of the soil
- concentrations of the compound.

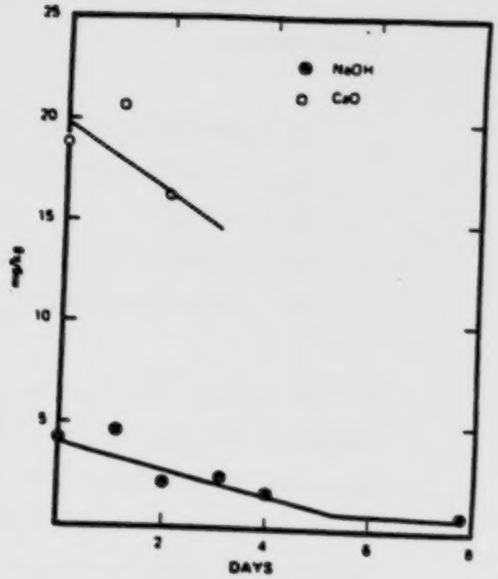
At the subject site, the soils were low in moisture content, were oxidizing, and exhibited soil pH values of 6.8 to 8.0. Under such conditions, parathion can be degraded slowly by alkali catalyzed hydrolysis reactions. The rate of these reactions increases with increasing soil pH. Parathion can also be biodegraded to O,O-Diethyl phosphoric acid. At a nearby site, it was shown that toxaphene will degrade anaerobically if reducing conditions can be achieved in the soil. It has also been observed that the loss of toxaphene by volatilization is enhanced by high soil moisture content. Other data indicated that toxaphene will degrade in the presence of strong alkali, by dechlorination reactions. This information can be used in identifying monitoring constituents and in performing interim and definitive corrective measures.

To test the feasibility of chemically degrading the contaminated soil, in situ, laboratory bench-scale tests were performed. Two treatments were evaluated, application of calcium oxide (quicklime) and sodium hydroxide (lye). Figure 15-4 shows that the pesticides were degraded by both of these strong alkalis.

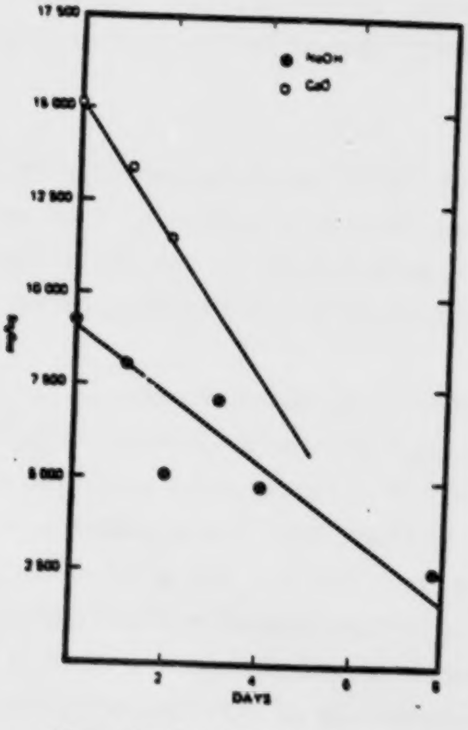
Those responsible for the remedial measures felt that the hot zone was too contaminated for in situ treatment to be effective over reasonable time periods. The upper 2 feet of soil from this area was excavated and transported to a secure landfill for disposal. However, the 1.7 acre residential area was treated in situ. To promote degradation, approximately 200 g/ft^2 of sodium hydroxide was applied using a tractor with a fertilizer-spreading attachment. A plow and disc were used to mix the sodium hydroxide into the soil to a depth of 1.5 feet. At 70 days after the application, concentrations of ethyl parathion had decreased by 76 percent, methyl parathion by 98 percent, and toxaphene by 45 percent.



Laboratory Bench Test, Ethyl Parathion Degradation



Laboratory Bench Test, Methyl Parathion Degradation



Laboratory Bench Test, Toxaphene Degradation

Figure 15-4. **Results of Laboratory Bench Test for Pesticide Degradation (from King et al., 1985)**

Case Discussion

Knowledge of the properties of a contaminant as well as its environment are important in assessing the potential for degradation, and this information can be used to identify monitoring constituents and conduct interim or definitive corrective measures. It may be possible to alter the site's physical or chemical characterisitcs to enhance degradation of contaminants. Under appropriate conditions, in situ treatment of contaminated soils can be an effective corrective measures method.

Reference

King, J., T. Tinto, and M. Ridosh. 1985. In Situ Treatment of Pesticide Contaminated Soils. Proceedings of the National Conference of Management of Uncontrolled Hazardous Waste Sites. Washington, D.C.

CASE STUDY 3: USE OF SPLIT-SPOON SAMPLING AND ON-SITE VAPOR ANALYSIS TO SELECT SOIL SAMPLES AND SCREENED INTERVALS FOR MONITORING WELLS

Point Illustrated

- HNU and OVA/GC screening provides a relative measure of contamination by volatile organics. It can be used to select soil samples for further analysis and can assist in the selection of screened intervals for monitoring wells.

Introduction

On-site vapor screening of soil samples during drilling can provide indications of organic contamination. This information can then be used to identify apparent hot spots and to select soil samples for detailed chemical analyses. In this manner, the use of higher powered laboratory methods can be focused in an effective way on the analysis of samples from critical locations and depths. The vapor analyses on site can also be helpful in selecting screened intervals for monitoring wells.

Facility Description and History

Manufacturing of plastics and numerous other chemicals has occurred at the site over the past 30 years. Some of the major products included cellulose nitrate, polyvinyl acetate, phenol, formaldehyde, and polyvinyl chloride. The entire site covers 1,000 acres. The location of the buildings and waste disposal areas are shown in Figure 15-5.

Three disposal methods are known to have been employed at the site. Readily combustible materials were incinerated in four burning pits, while non-combustibles were either disposed of in landfills or in a liquid disposal area. All on-site disposal operations were terminated in 1970, and monitoring programs have been implemented to identify contaminants, to defined and monitor ground water plumes, and to assess the resulting environmental impacts.

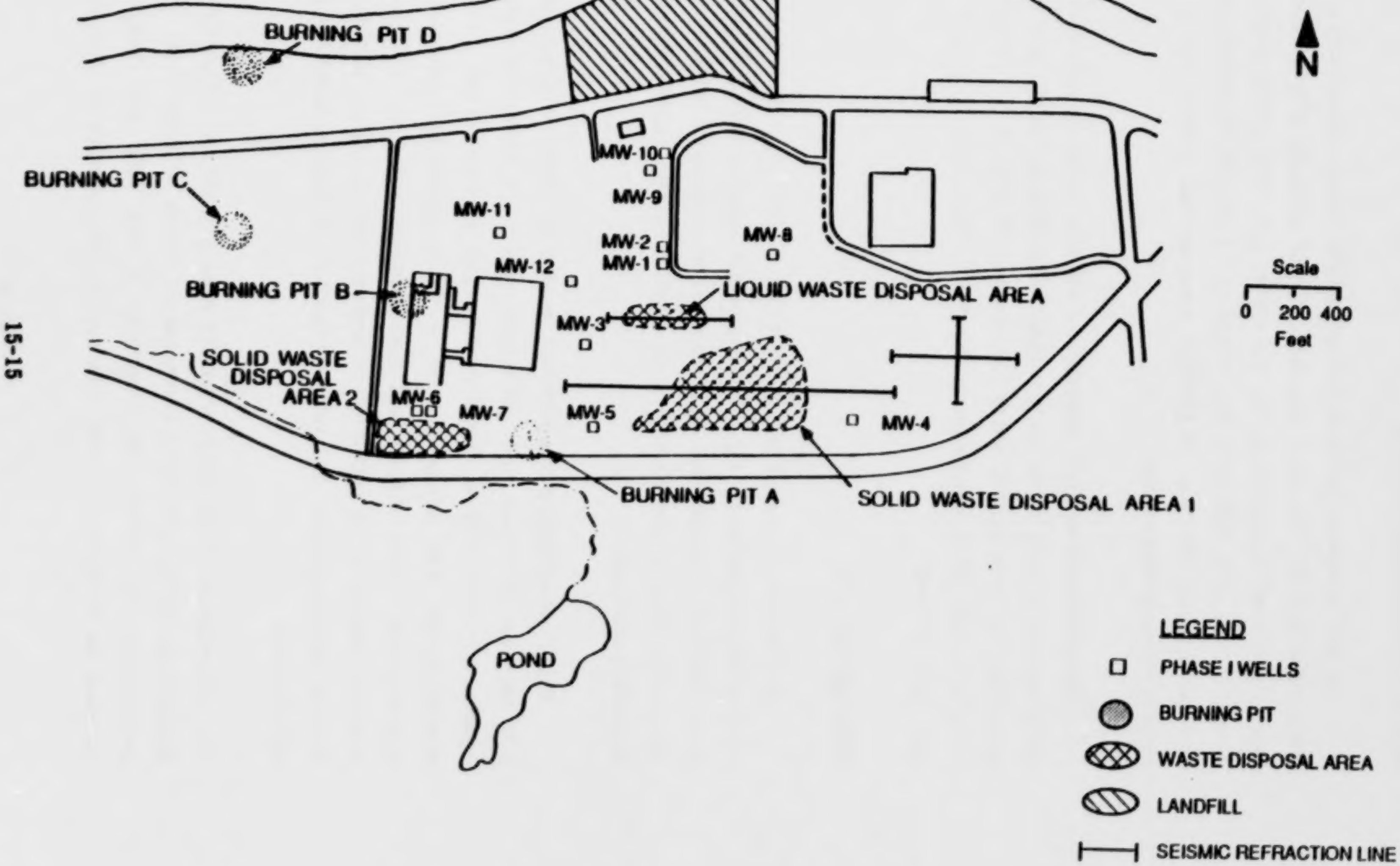

BURNING PIT D
N
BURNING PIT C
MW-10
MW-9
MW-11
MW-2
MW-1
MW-8
MW-12
BURNING PIT B
LIQUID WASTE DISPOSAL AREA
MW-3
Scale
0 200 400
Feet
SOLID WASTE DISPOSAL AREA 2
MW-6
MW-7
MW-5
MW-4
BURNING PIT A
SOLID WASTE DISPOSAL AREA I
POND
LEGEND
PHASE I WELLS
BURNING PIT
WASTE DISPOSAL AREA
LANDFILL
SEISMIC REFRACTION LINE

Figure 15-5. Site Plan Showing Disposal Areas and Phase I Well Locations

Geologic and Hydrologic Setting

The site is located in a well-defined glacial valley, adjacent to a river. Three major units underlie the site - one consisting of sand and gravel outwash deposits; two, fine-grained lacustrine sands; and three; till. The middle sand unit contains lenses of silt, clay and thin till. Only the deep till formation appears to be continuous across the site. A geologic cross-section beneath two of the disposal areas is shown in Figure 15-6.

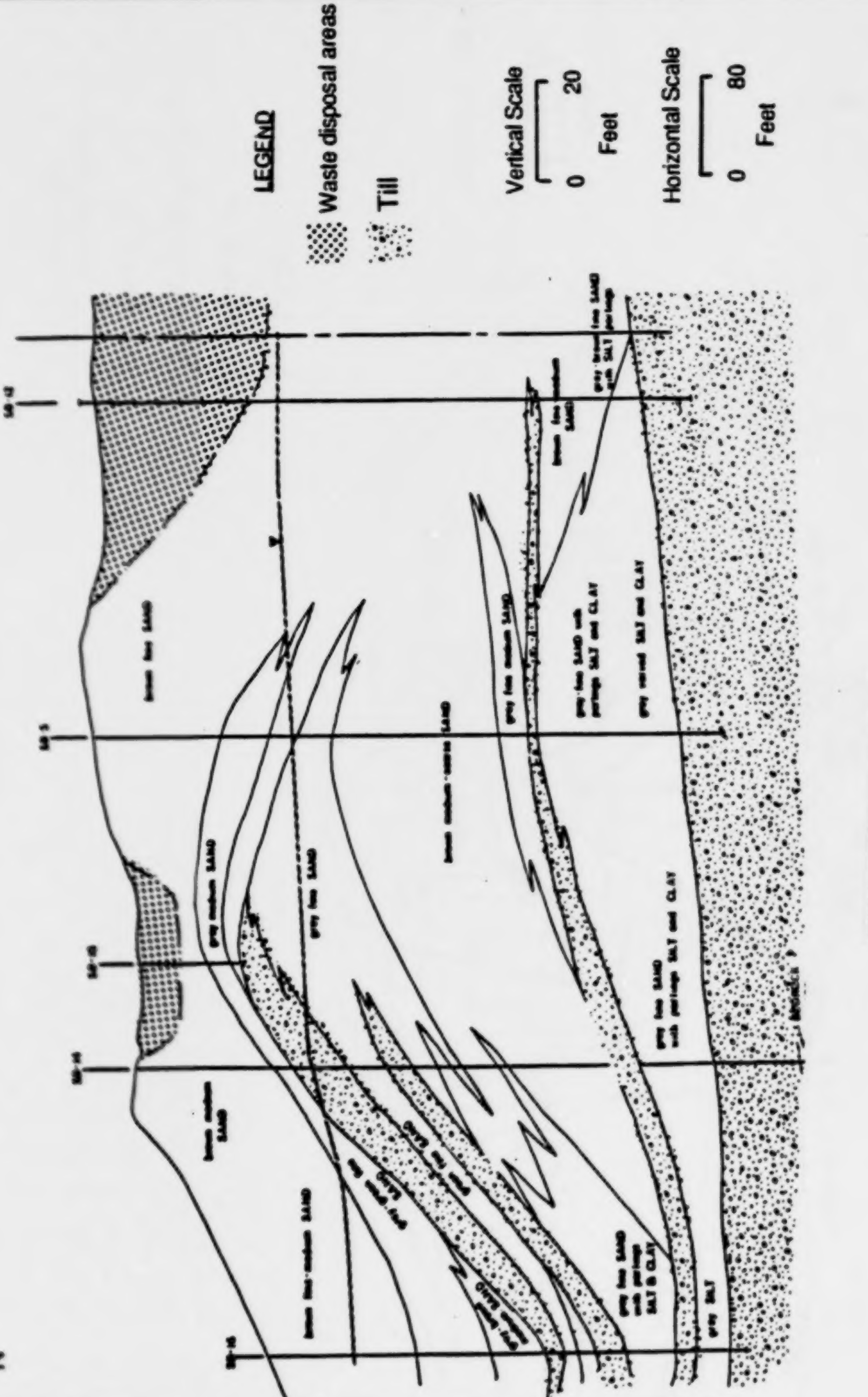
The ground-water flow direction at the site is to the northwest. However, there appears to be a buried stream channel running across the site which strongly influences the local ground water flow regime (Figure 15-7). Ground water from the site is thought to discharge to the river. The depth to ground water varies from 10 to 40 feet.

Sampling Program

As part of the remedial investigation at this site, 33 borings were drilled using a hollow-stem auger rig. Continuous soil samples were collected using split-spoon samplers. Samples for laboratory chemical analysis were selected based on the volatile organic concentrations detected by initial vapor screening of the soil samples in the field.

This field screening was achieved by placing a portion of each sample core in a 40 ml glass headspace vial. An aliquot of gas was extracted from the vial and injected directly into a portable OVA gas chromatograph (OVA/GC). The chromatograph was equipped with a flame ionization detector to identify hydrocarbons. Each sample was also screened using an HNU photoionization detector because of its sensitivity to aromatic hydrocarbons, particularly benzene, toluene and the xylenes. Following completion of drilling, gamma logs were run on all boreholes.

An example of the vapor screening results (HNU and OVA/GC) and geological and gamma logs for one of the boreholes are shown in Figure 15-8. The data shown demonstrate the differential sensitivity of the HNU and OVA/GC detectors. Because the OVA/GC is more sensitive to the organics of interest (aliphatics),


N
S
ELEVATION IN FEET ABOVE SEA LEVEL
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
brown fine-medium SAND
brown medium SAND
gray medium SAND
gray fine SAND
brown fine SAND
brown medium-coarse SAND
gray fine medium SAND
brown fine medium SAND
gray fine SAND with partings SILT & CLAY
gray fine SAND with partings SILT and CLAY
gray varved SILT and CLAY
gray SILT
BEDROCK
LEGEND
Waste disposal areas
Till
Vertical Scale
0
20
Feet
Horizontal Scale
0
80
Feet

Reproduced from best available copy.

Figure 15-6. Geologic Cross-Section Beneath Portion of Site

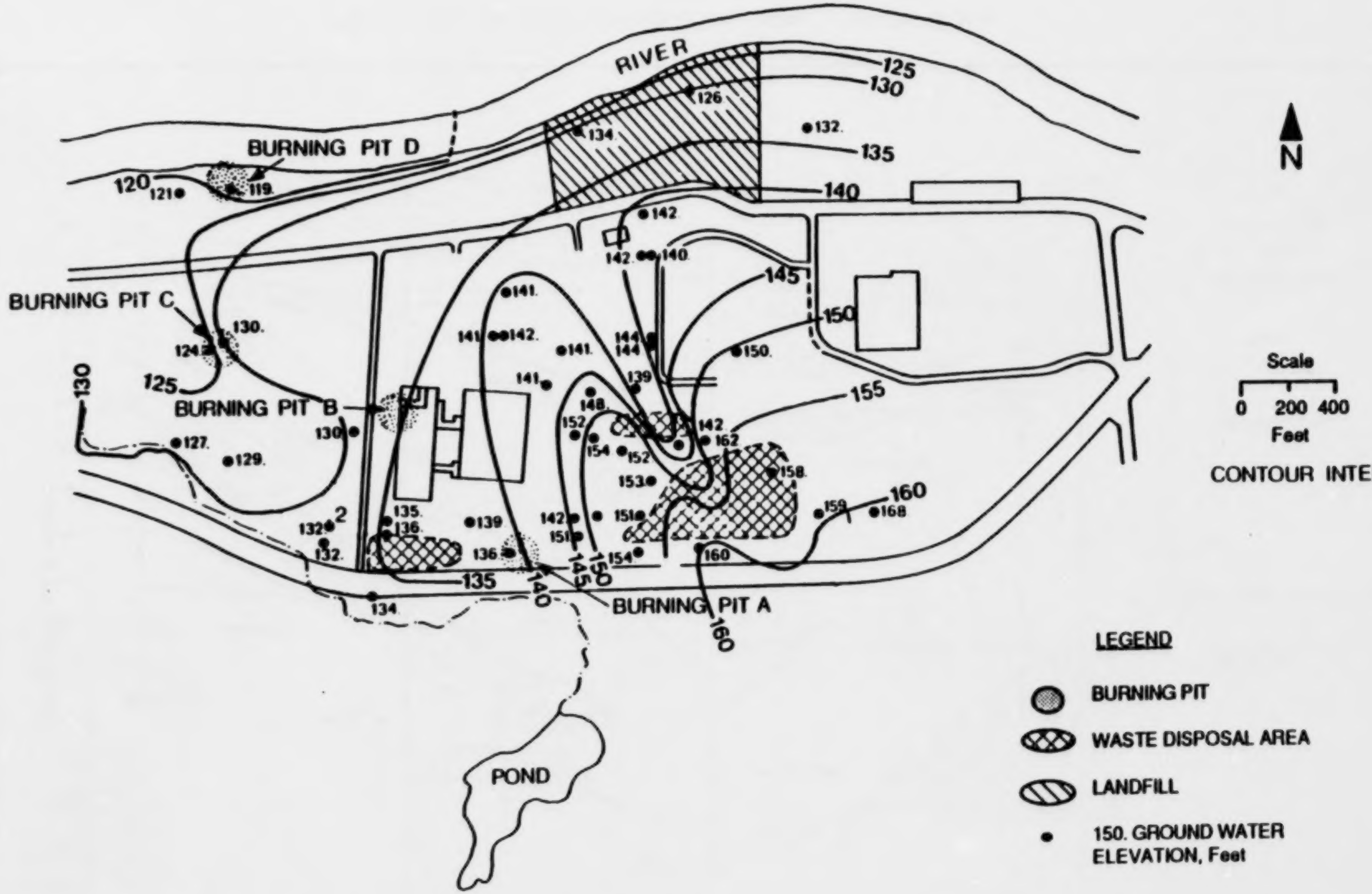
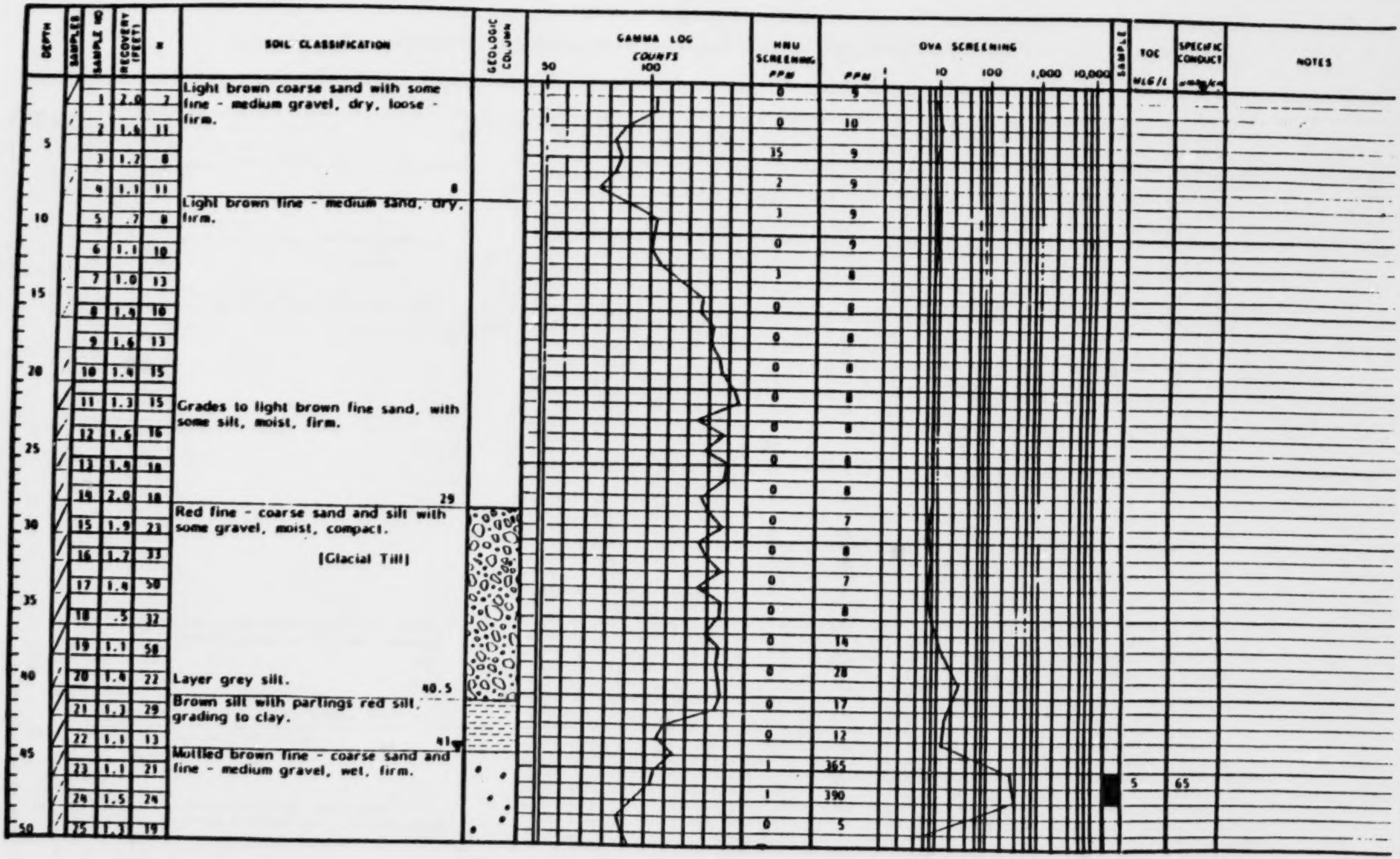

RIVER
BURNING PIT D
BURNING PIT C
BURNING PIT B
BURNING PIT A
POND
N
125
130
135
140
145
150
155
160
120
Scale
0 200 400
Feet
CONTOUR INTERVAL, 5 Feet
LEGEND
BURNING PIT
WASTE DISPOSAL AREA
LANDFILL
150. GROUND WATER ELEVATION, Feet

Figure 15-7. Ground Water Elevations in November 1984



SAMPLE NO	RECOVERY (FEET)	N	HNU SCREENING PPM	OVA SCREENING PPM
1	2.0	2	0	9
2	1.6	11	0	10
3	1.2	8	35	9
4	1.1	11	2	9
5	.7	8	1	9
6	1.1	10	0	9
7	1.0	13	1	8
8	1.4	10	0	8
9	1.6	13	0	8
10	1.4	15	0	8
11	1.3	15	0	8
12	1.6	16	0	8
13	1.4	18	0	8
14	2.0	18	0	8
15	1.9	23	0	7
16	1.7	33	0	8
17	1.4	50	0	7
18	.5	32	0	8
19	1.1	58	0	14
20	1.4	22	0	28
21	1.3	29	0	17
22	1.1	13	0	12
23	1.1	21	1	365
24	1.5	24	1	390
25	1.3	19	0	5

SOIL CLASSIFICATION

Light brown coarse sand with some fine - medium gravel, dry, loose - firm.

8

Light brown fine - medium sand, dry, firm.

Grades to light brown fine sand, with some silt, moist, firm.

29

Red fine - coarse sand and silt with some gravel, moist, compact.

[Glacial Till]

Layer grey silt.

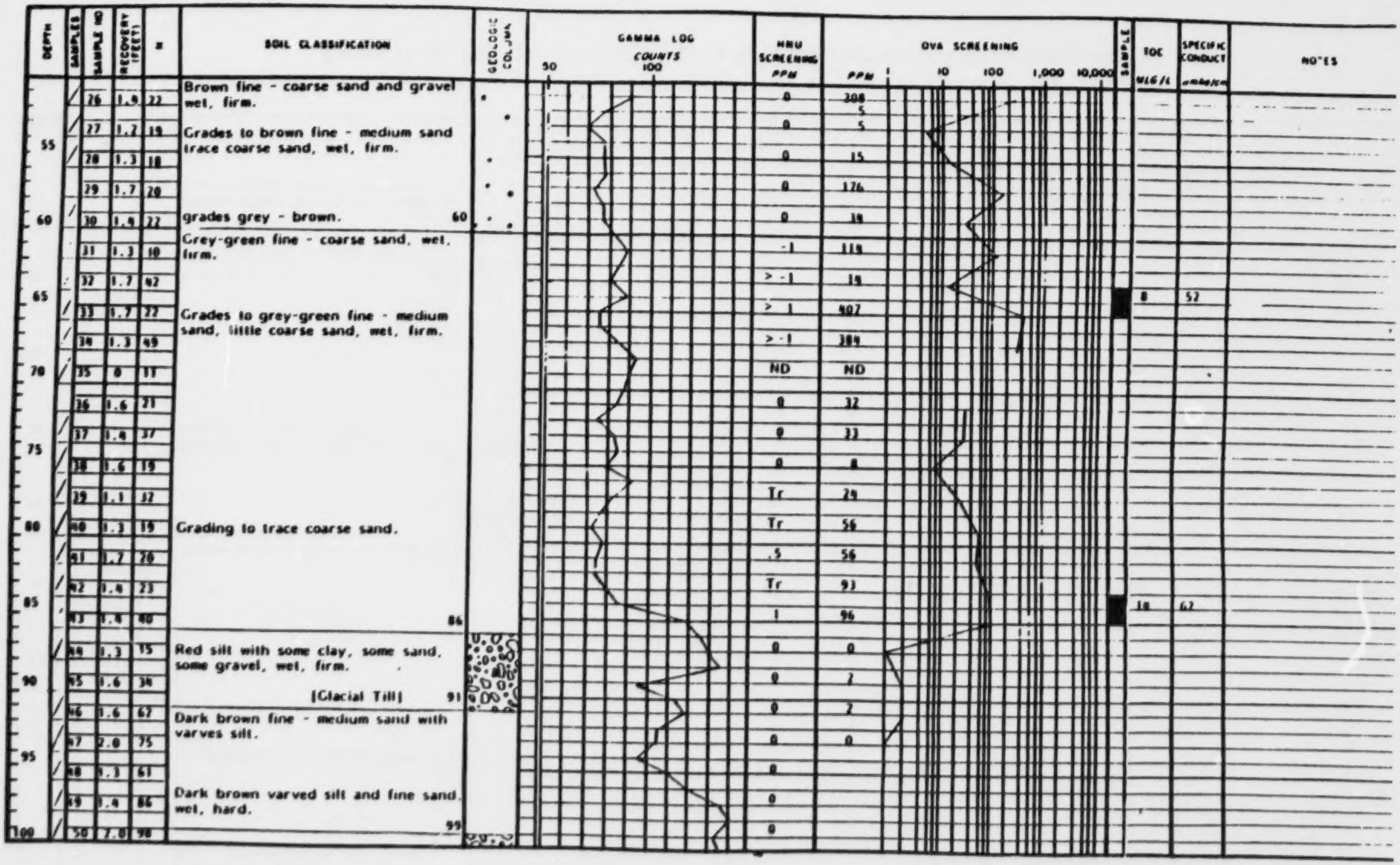
40.5

Brown silt with partings red silt, grading to clay.

41

Mottled brown fine - coarse sand and fine - medium gravel, wet, firm.

Figure 15-8. Example of Borehole Data Including HNV and OVA/GC Screening



DEPTH	SAMPLE NO	RECOVERY (FEET)	N	SOIL CLASSIFICATION	HNU SCREENING PPM	OVA SCREENING PPM	TOC MG/L	SPECIFIC CONDUCT µmho/cm
	26	1.9	22	Brown fine - coarse sand and gravel wet, firm.	0	308 5		
	27	1.2	19	Grades to brown fine - medium sand trace coarse sand, wet, firm.	0	5		
55	28	1.3	18		0	15		
	29	1.7	20		0	176		
60	30	1.4	22	grades grey - brown. 60	0	39		
	31	1.3	10	Grey-green fine - coarse sand, wet, firm.	-1	119		
	32	1.7	42		> -1	19		
65	33	1.7	22	Grades to grey-green fine - medium sand, little coarse sand, wet, firm.	> 1	407	8	52
	34	1.3	49		> -1	384		
70	35	0	11		ND	ND		
	36	1.6	21		0	32		
	37	1.4	37		0	33		
75	38	1.6	19		0	8		
	39	1.1	32		Tr	29		
80	40	1.3	19	Grading to trace coarse sand.	Tr	56		
	41	1.7	20		.5	56		
	42	1.4	23		Tr	93		
85	43	1.4	40	86	1	96	18	62
	44	1.3	15	Red silt with some clay, some sand, some gravel, wet, firm.	0	0		
90	45	1.6	34	(Glacial Till) 91	0	2		
	46	1.6	62	Dark brown fine - medium sand with varves silt.	0	2		
	47	2.0	75		0	0		
95	48	1.3	61		0			
	49	1.4	86	Dark brown varved silt and fine sand, wet, hard.	0			
100	50	2.0	98	99	0			

Figure 15-8. Example of Borehole Data Including HNV and OVA/GC Screening (Continued)

these results were used to select samples for detailed chemical analysis in the laboratory. As shown in Figure 15-8, samples in zones with OVA/GC readings of 390 ppm (45 feet depth), 407 ppm (65 feet depth), and 96 ppm (85 feet depth) were selected. In the laboratory, samples were first analyzed for total organic carbon (TOC). The ten samples with the highest TOC levels were then analyzed for purgeable organics using EPA Method 50-30 and extractable organics using EPA Method 82-50 (U.S. EPA, 1982 - Test Methods for Evaluating Solid Waste, SW 846).

The OVA/GC results were also used to select well screen intervals. Examination of the data in Figure 15-8 shows that the highest levels of volatile organics (by OVA/GC) were found at a depth of 65 feet. In addition, the gamma and geologic logs indicated that the permeable medium at that depth was coarse sand which would be a suitable location for the placement of a well screen. Thus, a 5 foot stainless steel screen was set over the depth interval from 62 to 67 feet.

Case Discussion

This sampling program incorporated field techniques that detect the presence of volatile organics and allow on-site, rapid identification of likely contaminant "hot spots" for detailed laboratory anaysis and to select depths for monitoring well screens.

CASE STUDY 4: CONDUCTING SITE INVESTIGATIONS IN TWO PHASES

Points Illustrated

- When ground water contamination is known or suspected at a site, a set of initial borings is typically made (Phase I) to determine site hydrogeologic characteristics and to identify areas of soil and ground water contamination (Phase I).
- These findings are then used to select well locations to fully delineate the extent of contamination during a second phase of the investigation (Phase II).

Introduction

To identify the extent of ground water contamination in an efficient manner, information is needed on the ground water flow regime. Phase I investigations typically focus on determining site geologic characteristics and ground water flow directions and velocities. Waste sources are also identified. The Phase I results are then used in planning the Phase II investigation to determine the extent of contamination and to refine estimated rates of contaminant migration.

Facility and Site Description

Descriptions of the facility and site geologic characteristics were included in Case Study 3.

Sampling Program

The Phase I sampling program included geophysical surveys, water level monitoring, soil sampling, and ground water quality sampling. Three seismic refraction lines were run to estimate the depth to the top of the deep till. The top of the till was found to occur at a depth of 70 to 120 feet over most of the site.

Available historical data indicated that the general ground water flow direction was to the northwest across the site. The ground water was thought to discharge to the river. This information and historical drawings and maps of known disposal areas were used to locate the Phase I borings (see Figure 15-5 in Case

Study 3). One well (MW4) was located on the suspected upgradient side of the site. The other wells were located near waste sources to determine which sources appeared to be contributing contaminants to the ground water. For example, two wells (MW6 and 7) were located immediately downgradient of solid waste disposal area #2. To determine the presence of vertical gradients, three two-well clusters were drilled—each with one well screened just below the water table and a second well screened considerably below that at the base of the till.

The results of the Phase I investigation indicated that all the wells contained solvents. Thus, investigations of the waste sources and contaminant plumes had to be continued in Phase II. The highest solvent concentrations were found in wells located near the liquid waste disposal area where downward vertical gradients were present. The contaminants had migrated down to depths of 75 feet in this portion of the site. The Phase I data confirmed the general northwest ground water flow direction but showed a complex flow pattern near the buried stream channel. A second concern was whether observed lenses of fine-grained till under the site were producing zones of perched water which could be contaminated.

Based on the Phase I results, a Phase II monitoring program was designed to determine the extent of contamination around the major disposal sites. Typically, 2 soil borings were installed - 1 up and 1 downgradient of the waste source. Because of the high solvent concentrations observed in the wells downgradient of the liquid disposal area, a more intensive field investigation of this area was included in Phase II. Instead of 2 borings per waste source at the liquid disposal area, 11 soil borings and 5 new monitoring wells were drilled. This represented one-third of the total effort for the entire 1,000 acre site. The total number of Phase II soil borings was 33 (Figure 15-9) and the total number of Phase II wells was 15 (Figure 15-10). The Phase II data indicated that most of the solvent contamination originated from the liquid disposal area and not from solid waste disposal area #1 which is located upgradient of the liquid disposal area. The phase II data did identify PCBs from solid waste disposal area #1 but not from any of the other sources. This was consistent with site records indicating that transformers had been disposed at this site.

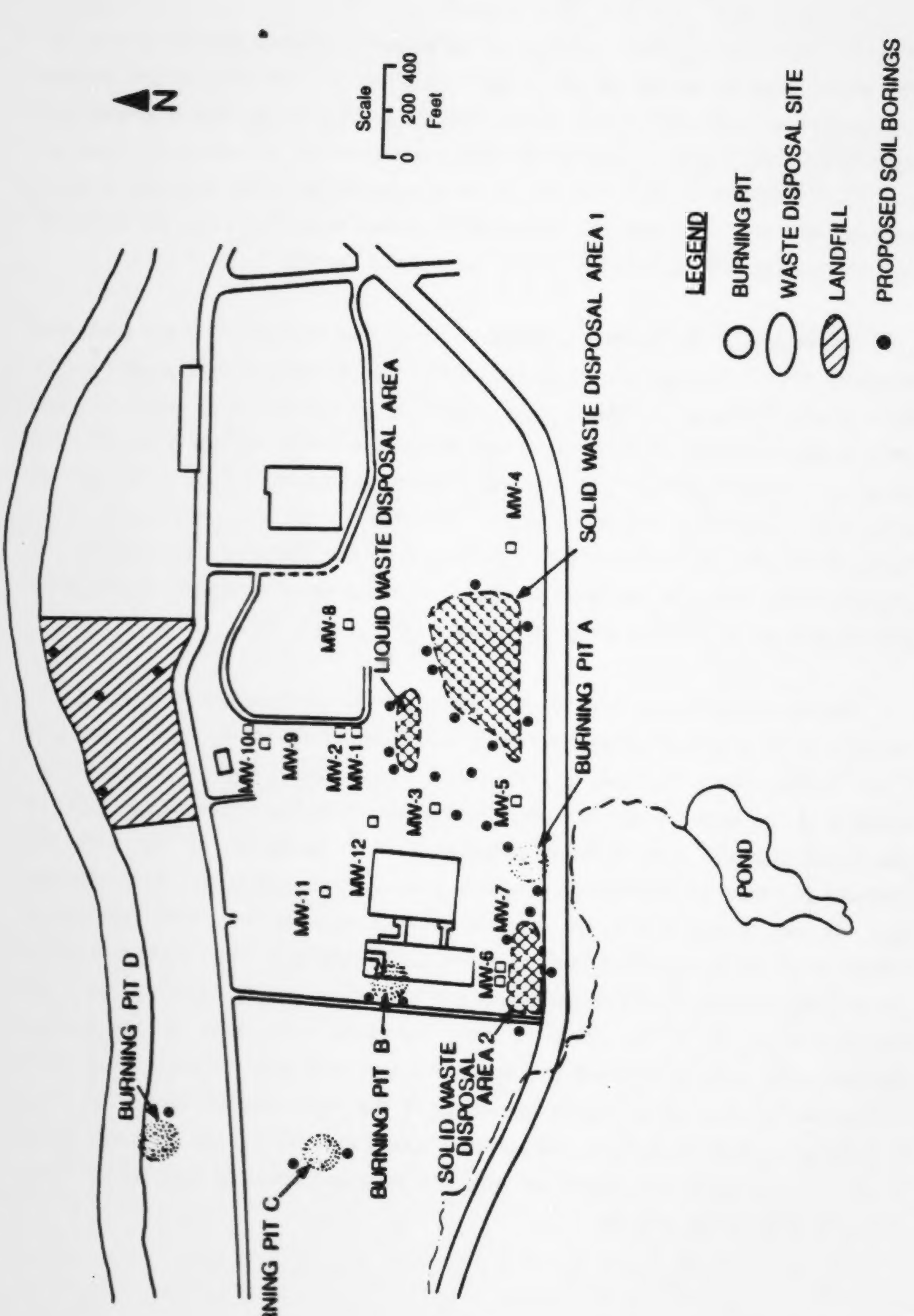

BURNING PIT D
BURNING PIT C
BURNING PIT B
SOLID WASTE DISPOSAL AREA 2
MW-6
MW-7
MW-11
MW-12
MW-10
MW-9
MW-2
MW-1
MW-3
MW-5
MW-8
LIQUID WASTE DISPOSAL AREA
BURNING PIT A
SOLID WASTE DISPOSAL AREA 1
MW-4
POND
N
Scale
0 200 400
Feet
LEGEND
BURNING PIT
WASTE DISPOSAL SITE
LANDFILL
PROPOSED SOIL BORINGS

Figure 15-9. Proposed Phase II Soil Borings

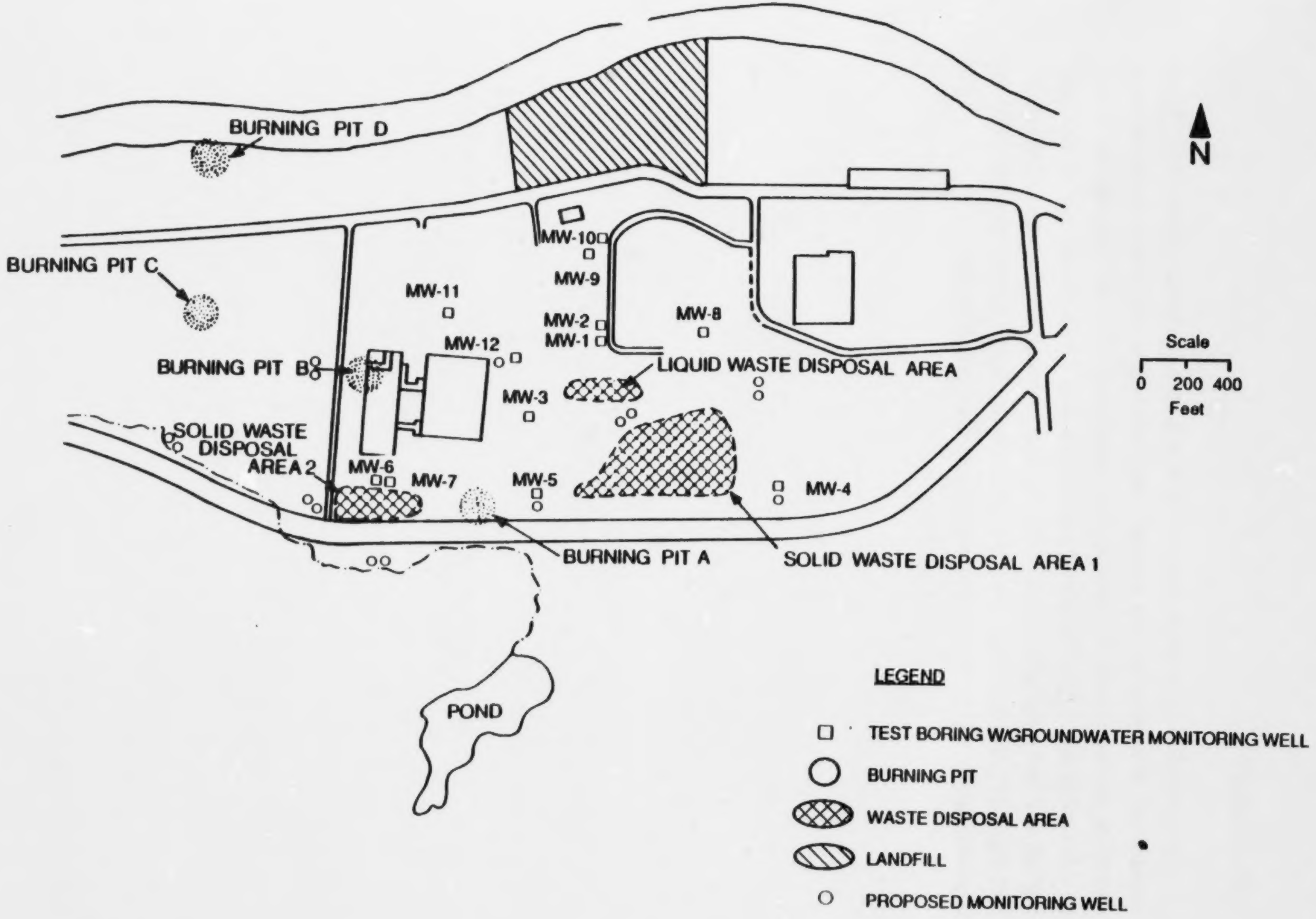

BURNING PIT D
BURNING PIT C
BURNING PIT B
SOLID WASTE DISPOSAL AREA 2
MW-10
MW-9
MW-11
MW-2
MW-1
MW-8
MW-12
MW-3
MW-6
MW-7
MW-5
MW-4
LIQUID WASTE DISPOSAL AREA
BURNING PIT A
SOLID WASTE DISPOSAL AREA 1
POND
N
Scale
0 200 400
Feet
LEGEND
TEST BORING W/GROUNDWATER MONITORING WELL
BURNING PIT
WASTE DISPOSAL AREA
LANDFILL
PROPOSED MONITORING WELL

Figure 15-10. Proposed Phase II Monitoring Wells

Case Discussion

Investigation of a large complex site is best conducted sequentially. Basic information is needed on site geologic characteristics and ground water seepage velocities and directions to appropriately locate wells for determining the extent of contamination. Thus, the initial installation of a limited number of exploratory borings and wells can provide the data needed to design a complete and effective investigation. Results from the latter can then be used to determine the need for remedial action and to evaluate alternative remediation methods.

CASE STUDY 5: MONITORING BASEMENT SEEPAGE

Point Illustrated

- Basement monitoring can be used to estimate the extent of contaminant migration.

Introduction

Leachate produced in a landfill can be transported downgradient in ground water by advection and dispersion. Shallow ground water may surface and seep into basements.

Site Description

A channel, originally constructed as part of a hydroelectric power generation system, was used as a disposal site for a variety of chemical wastes from the 1920s through the 1950s. More than 21,000 tons of waste were dumped in and around the site before its closure in 1952. After closure, homes and a school were constructed on and around the site. In the 1960s, residents began complaining of odors and residues. During the 1970s, the local water table rose, and contaminated ground water seeped into nearby basements.

Geologic and Hydrologic Setting

Figure 15-11 shows a cross-section of the site. The site has both a shallow and a deep aquifer. The shallow aquifer consists of approximately 5 feet of interbedded layers of silt and fine sands overlying beds of clay and glacial till. The deeper aquifer is a fractured dolomite bedrock overlying a relatively impermeable shale. Travel times from the shallow to the deeper aquifer are relatively long. Contamination has occurred in the shallow aquifer because of the "bathtub effect". The impermeable channel filled because of infiltration, and leachate spilled over the channel sides. The leachate contaminated the shallow ground water and was transported laterally in this system.

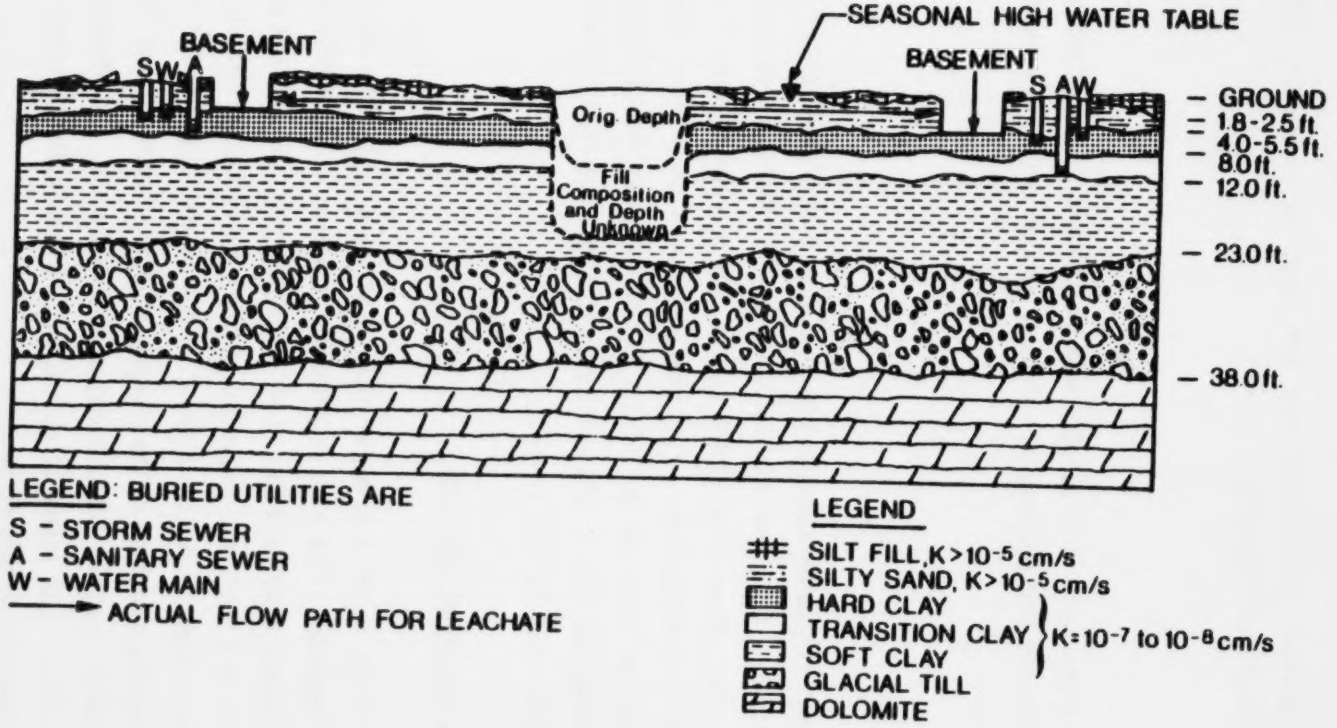

SEASONAL HIGH WATER TABLE
BASEMENT
SW A
BASEMENT
S AW
Orig. Depth
Fill Composition and Depth Unknown
GROUND
1.8-2.5 ft.
4.0-5.5 ft.
8.0 ft.
12.0 ft.
23.0 ft.
38.0 ft.
LEGEND: BURIED UTILITIES ARE
S - STORM SEWER
A - SANITARY SEWER
W - WATER MAIN
ACTUAL FLOW PATH FOR LEACHATE
LEGEND
SILT FILL, K>10-5 cm/s
SILTY SAND, K>10-5 cm/s
HARD CLAY
TRANSITION CLAY
SOFT CLAY
K=10-7 to 10-8 cm/s
GLACIAL TILL
DOLOMITE

Figure 15-11. Geologic Cross-Section Beneath Site

Sampling Program

The houses surrounding the channel were grouped into three sets (upgradient, downgradient, and on-site) based on preliminary data on the underlying strata and ground water flow directions. Four houses from each group were selected for sampling for a total of 12 houses. Samples of water and sediments were collected from the sump pump wells in each basement. Water samples were collected at times when the sump pumps were running and 24 hours after pumping had ceased. Water and sediment samples were analyzed for purgeable and extractable organics. Benzene, carbon tetrachloride, chloroform, and trichloroethylene (TCE) were found in the water samples. Water samples taken while the sump pumps were running had higher concentrations of volatile organics. Sediment samples contained PCBs and dioxin, possible due to cosolvation. Relatively immobile organics can become dissolved in another more mobile solvent. The mobile solvent containing traces of other organics can be advected along with the water. This process (cosolvation) is one facet of enhanced transport which has recently been proposed as a possible mechanism for the observed mobility of otherwise immobile organics. Samples of water and sediments from storm drains were also collected and analyzed to determine if discharges from the sumps to the storm drains were a significant source of organics in the storm runoff.

In addition to determining water quality, indoor and outdoor air quality was measured in the basements at each house. Tenax and polyurethane foam tubes were placed in air monitoring systems in each basement to measure 12-hour average concentrations of volatile organics (e.g., carbon tetrachloride, benzene, TCE) and semi-volatile organics (e.g., pesticides). Volatile organics were present in the indoor air samples but semi-volatile organics were not detected. The highest volatile organic concentrations were observed during the time when the sump pumps were operating.

Case Discussion

At sites where hydrogeologic factors favor shallow lateral ground water flow, initial site characterization may involve sampling of basements. Results from such an initial site characterization can provide information on contaminant migration which can be used in the design and implementation of detailed soil and ground water monitoring programs.

The results of the sampling program described above led to the evacuation and destruction of a number of homes. A system of monitoring wells has been installed to replace the basement sump sampling sites. The shallow aquifer is being pumped and treated to arrest contaminant migration.

CASE STUDY 6: USE OF PREDICTIVE MODELS TO SELECT LOCATIONS FOR GROUND WATER MONITORING WELLS

Point Illustrated

- Simple mathematical models can be used to estimate the longitudinal and transverse spread of a contaminant plume. Wells can then be located in areas expected to have elevated contaminant concentrations and in areas thought to be both up and downgradient of the plume.

Introduction

The use of mathematical models to estimate the migration of contaminants can be helpful for several reasons, including: 1) fewer wells may be needed to delineate a contaminant plume, and 2) wells can be rationally located in an attempt to determine the maximum concentrations in a plume, its furthest extent, and locations where concentrations should be at background levels.

Facility Description

The site was an electronics manufacturing plant that had been in operation for 20 years. Four large diameter, rock-filled "dry wells" had been used to dispose of solvents and process wastes. These disposal units were between 35 and 60 feet deep. Depth to ground water was over 460 feet. Disposal Units 1 and 2 had received paint wastes and solvents, including trichloroethylene (TCE) and tetrachloroethylene, between 1964 and 1979. Disposal Units 3 and 4 had been used to dispose of plating solutions and spent acids between 1971 and 1977. These solutions contained copper, chromium, nickel, lead and tin. All the disposal units were closed in 1982. Exact quantities of wastes disposed are not known.

Geologic and Hydrologic Setting

The site is located in a large alluvial basin in an arid region. The basin alluvium is over 1,000 ft thick and consists of an upper sand and gravel unit, a middle silty-clay unit, and a lower sand and gravel unit. Granitic bedrock underlies the unconsolidated formations. Priot to large withdrawals of ground water, the upper unit had been saturated. At present, the silty-clay unit acts as an aquitard so that water beneath it is under confined conditions. The piezometric surface is now 350 ft below the land surface. In addition to a drop in water level elevations, the ground water flow direction has changed over the years from east to north in response to changing pumping regimes. Estimated horizontal seepage velocities have varied from 10 to 40 feet/year.

Site Investigation

In 1982, city water officials discovered TCE in water samples from wells located within 3 miles of the site. On its own initiative, the site owner began a pre-remedial investigation, and then later a remedial investigation, to determine whether its site could be a source of the TCE. The pre-remedial investigation provides an example of how simple models can be used to determine well locations. The pre-remedial investigation included sampling nearby wells and drilling a single deep sampling well (over 500 feet deep).

Original plans called for locating the deep monitoring well between the waste disposal units in an attempt to determine whether solutes had contaminated the underlying ground water. However, site constraints including an overhead power transmission line, underground power lines and major manufacturing buildings, necessitated that the monitoring well site be moved. The next step was to determine an appropriate location for this well. Because of the changing ground water flow direction at this site, it was decided to use a simple mathematical model to predict the areal extent of contamination from the disposal units. The results would then be used in selecting a new location for the deep monitoring well. Data were collected to determine historical ground water gradients, pumping histories, and aquifer hydraulic characteristics (permeability, porosity). Following data collection, a vector analysis model "the method of Mido" (1981) was used to predict plume evolution. The results showed that the major plume migration was to the north (Figure 15-12). Thus, the well was located north of the disposal units at a distance of 60 feet from Unit 4.

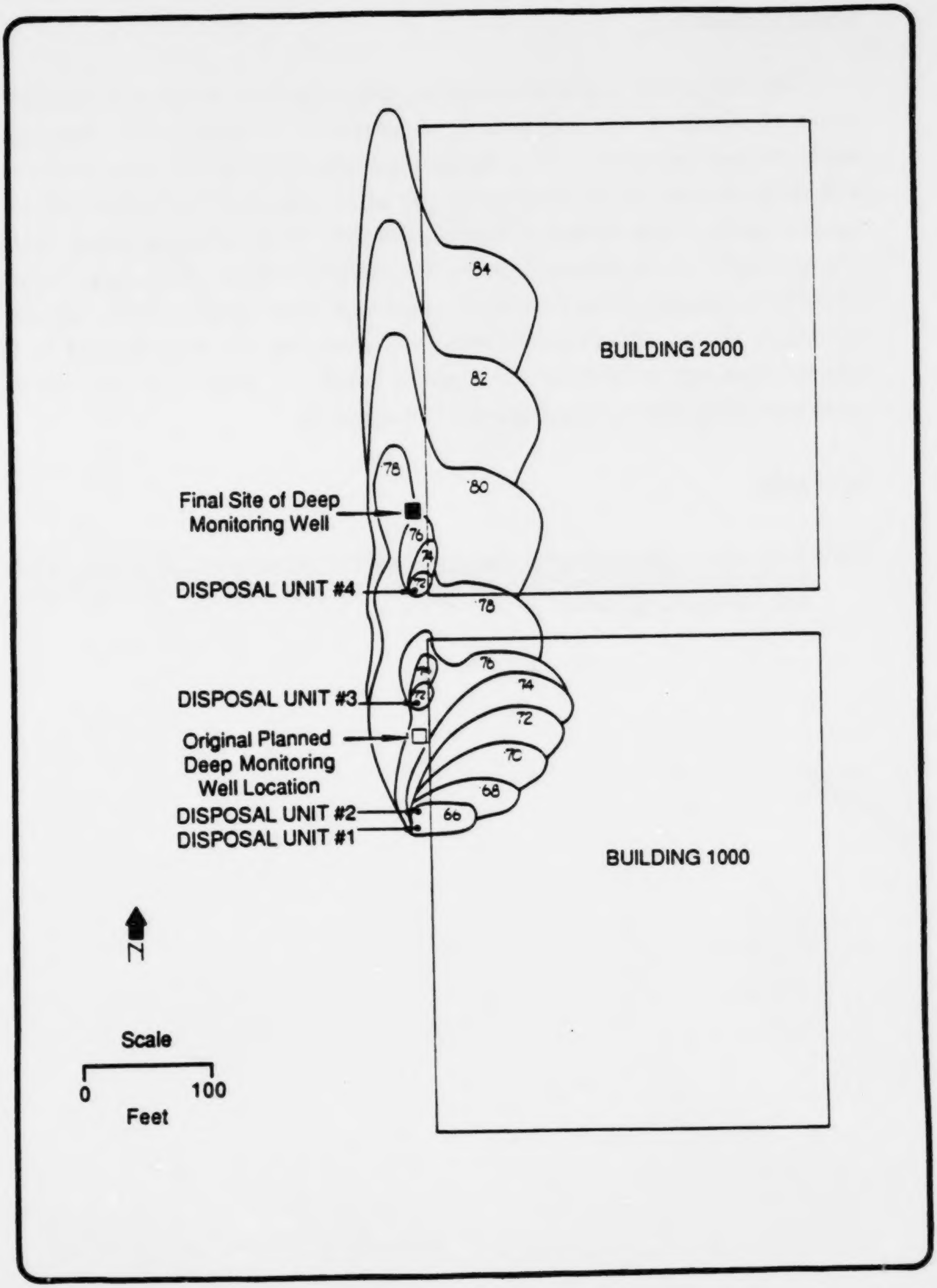

BUILDING 2000
BUILDING 1000
84
82
80
78
78
76
74
72
78
76
74
72
70
68
66
Final Site of Deep Monitoring Well
DISPOSAL UNIT #4
DISPOSAL UNIT #3
Original Planned Deep Monitoring Well Location
DISPOSAL UNIT #2
DISPOSAL UNIT #1
N
Scale
0
100
Feet

Figure 15-12. Estimated Areal Extent of Hypothetical Plumes from Four Wells

Case Discussion

Use of a model to predict potential plume migration at this site provided a means of evaluating the long-term consequences of changing ground water flow directions and velocities. Thus, the pre-remedial investigation deep monitoring well could be sited in the direction of net plume displacement, rather than at a location which might have had a low probability of intercepting contaminated ground water. A concentration below the detection limits from a well located beyond the expected plume boundaries would have been inconclusive (for example, see Figure 15-13). However, the deep monitoring well was located close to the disposal units and in the direction of plume migration. Additional wells are now being planned for the full-scale remedial investigation.

Reference

Mido, K.W. 1981. An economical approach to determining extent of ground water contamination and formulating a contaminant removal plan. Ground Water, Vol. 19, No. 1, pp. 41-47.

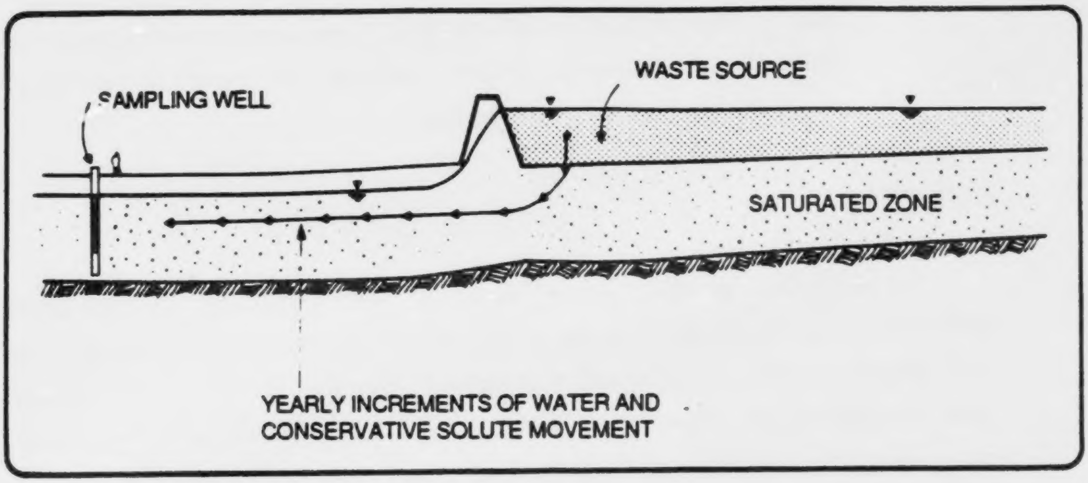

SAMPLING WELL
WASTE SOURCE
SATURATED ZONE
YEARLY INCREMENTS OF WATER AND CONSERVATIVE SOLUTE MOVEMENT

Figure 15-13. **Consideration of Solute Migration Rates in Siting Sampling Wells.**

If a monitoring well is sited farther downgradient than solutes could have traveled in the time since disposal, low concentrations in the well would certainly not prove that ground water contamination had not or was not occurring. Prior to locating a well, seepage velocities should be estimated (V_s= KI/P where V_s = seepage velocity for conservative solutes, K = hydraulic conductivity, I = ground water gradient, and p = effective porosity). Using these estimates, and the age of the disposal unit, T, an approximate migration distance, D, can be computed (D = T/V_s) for conservative solutes associated with the waste. For soil interactive solutes, migration distances will be less. Methods for estimating these distances are given by Mills et at. (1985). By properly siting monitoring wells, one can avoid unnecessary expense or embarrassment.

CASE STUDY 7: MONITORING AND CHARACTERIZING GROUND WATER CONTAMINATION WHEN TWO LIQUID PHASES ARE PRESENT

Point Illustrated

- Monitoring and characterizing ground water contamination when two or more liquid phases are present requires knowledge of the physical and chemical properties of each phase.

Introduction

Increasingly, ground water supplies are becoming contaminated with immiscible organic liquids. Organic liquids such as PCB-contaminated transformer oils, petrochemical solvents, and motor fuels, because of their nature, often form a second liquid phase. This separate liquid, in either the vadose or saturated ground water zone, represents a problem in multiphase flow. It is necessary to understand how these separate phases behave when designing monitoring and sampling programs for sites contaminated with such liquids. Techniques commonly used for single-phase flow systems may not be appropriate.

Site Description

The facility is a transformer manufacturing plant which experienced a major discharge of polychlorinated biphenyls (PCBs) and trichlorinated benzenes (TCBs). The discharge resulted from a break in a buried pipeline, but surface spillage may have also occurred during production. The volume and duration of the subsurface discharge is not known; neither is the quantity released by above ground spillage.

Geological and Hydrologic Setting

The site is underlain by 10 feet of fill over lacustrine clay which varies in thickness from 20 to 30 feet. Fractures with opening of approximately 0.1 cm have been observed in the clay. Below the clay lies a thin silt layer. Below that is a 40 to 60 foot thick layer of glacial till composed of fine sand near the top, and gravel, sand, and silt below.

Perched water about 3 feet deep flows laterally in the fill. The permanent water table, located in the till, is partially confined. Piezometric levels in this latter system are between 25 and 30 feet below the land surface.

Sampling Program

Over 1000 soil samples were taken as part of the site investigation. A mobile atmospheric pressure chemical ionization mass spectrophotometer (APCI/MS) was employed for rapid, on-site characterization of soil samples. This instrument can detect PCBs down to a minimum concentration of 100 mg/kg. About 20 percent of the PCB analyses were replicated by conventional gas chromatography.

Granular dry materials were sampled from an auger with care taken in cleaning sampling equipment to avoid cross-contamination. In taking samples from the clay, special effort was made to sample the surfaces of obvious fractures. This was done to maximize the changes of detection of PCBs in largely uncontaminated soil. Due to dilution, large bulk samples can prevent the detection of contaminant migration through fractures in low permeability soils.

Vertically, the soil sampling program showed PCBs to be distributed in a non-homogeneous pattern within the clay zone. Concentrations of PCBs greater than 500 mg/kg PCBs were detected. The lateral spreading of PCBs throughout the fill was much more extensive than the vertical movement. This could be due to the nature of the discharge/spillage, pressure from the broken pipe, or the fact that the fill is more permeable than the clay. The PCBs appear to have formed a layer along the fill/clay interface. Movement of PCBs more than 300 feet laterally from the original spill site has been confirmed.

Based on the soil sampling results, 12 well locations (Figure 15-14) were chosen to further characterize the site. Four boreholes were drilled into the till aquifer. One well, 686-B, was placed upgradient of the spill site with a screened interval between depths of 45 and 50 feet. The three downgradient wells in the till aquifer were screened over different intervals to increase the possibility of detecting a separate organic liquid layer. The screened intervals used were at depths 45 to 50 feet (well 686-A), 50 to 55 feet (well 686-C), and 55 to 60 feet

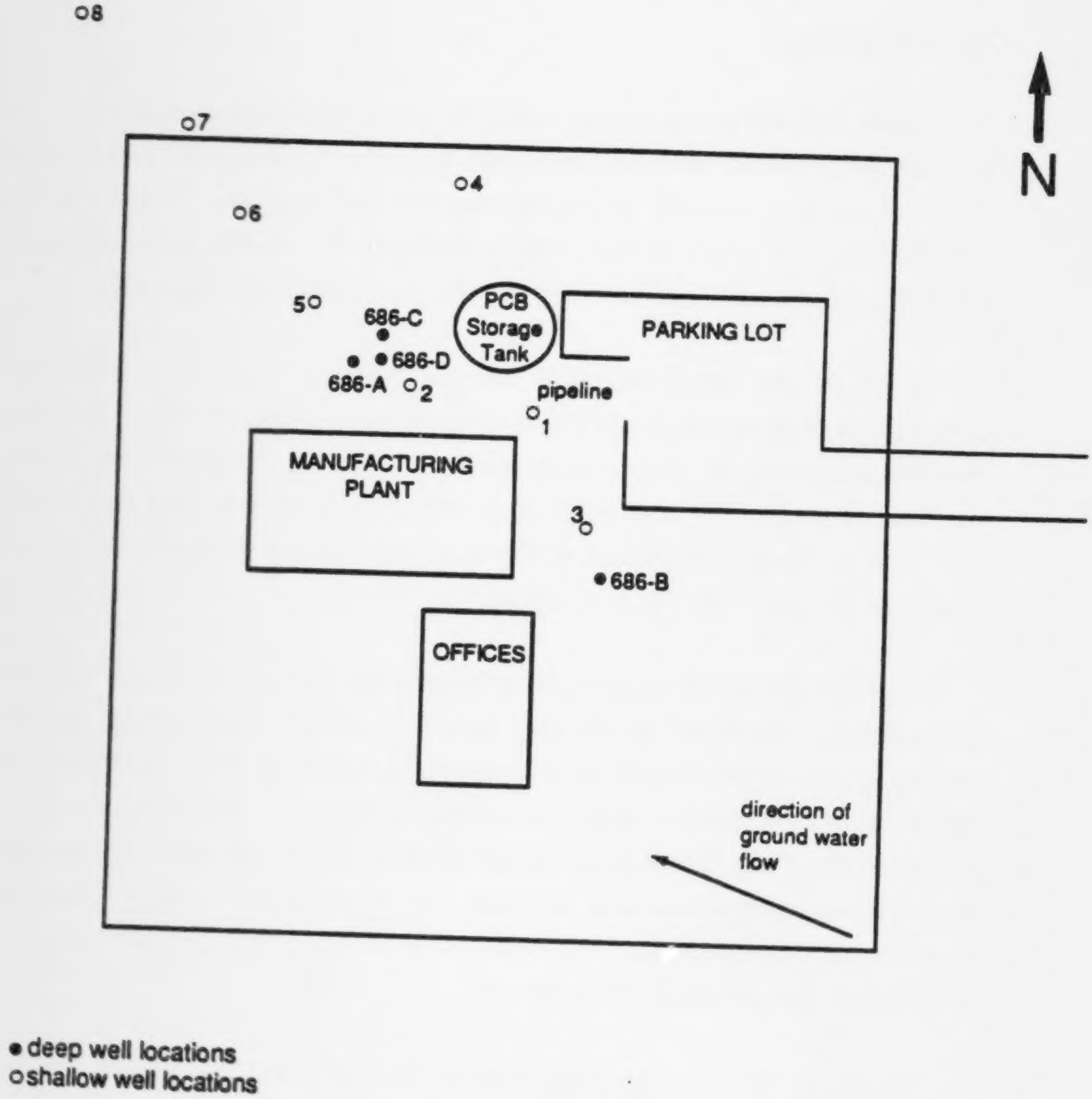

o8
o7
o4
o6
5o
686-C
PCB Storage Tank
PARKING LOT
686-D
686-A
o2
pipeline
o1
MANUFACTURING PLANT
3o
686-B
OFFICES
N
direction of ground water flow
● deep well locations
○ shallow well locations

Figure 15-14. Well Locations and Plant Configuration

(well 686-D). Eight wells were also placed in the fill to monitor the perched water (Figure 15-14). The fill is approximately 10 feet deep and a layer of PCBs was suspected at the fill/clay interface. The depth of the perched water fluctuates between 7 and 8 feet. Six of the eight wells in the fill, 1, 3, 4, 6, 7, and 8, are screened from 7 to 10 feet. Samples from wells 1, 6, 4, and 7 showed PCB levels much higher than the solubility limits. The sampling results suggest that two separate liquid layers exist at these locations and that the liquids are being mixed during sampling. Wells 2 and 5 were screened from 5 to 8 feet to determine if a floating liquid layer was present. Again, samples having concentrations far in excess of solubility limits indicated the existence of a layer of organic liquid.

Case Discussion

Ground water systems contaminated with immiscible liquids require special attention. Well screen intervals should be placed to intercept flow along boundaries between soil layers of differing permeabilities and at water table surfaces. Sampling results must also be interpreted properly. Samples showing contaminant concentrations far in excess of solubility limits may indicate that two layers of different liquids are being pumped and mixed.

Finally, Figure 15-15 is offered as an illustration of the types of complexity which can be encountered with immiscible liquids having densities both greater than and less than water.

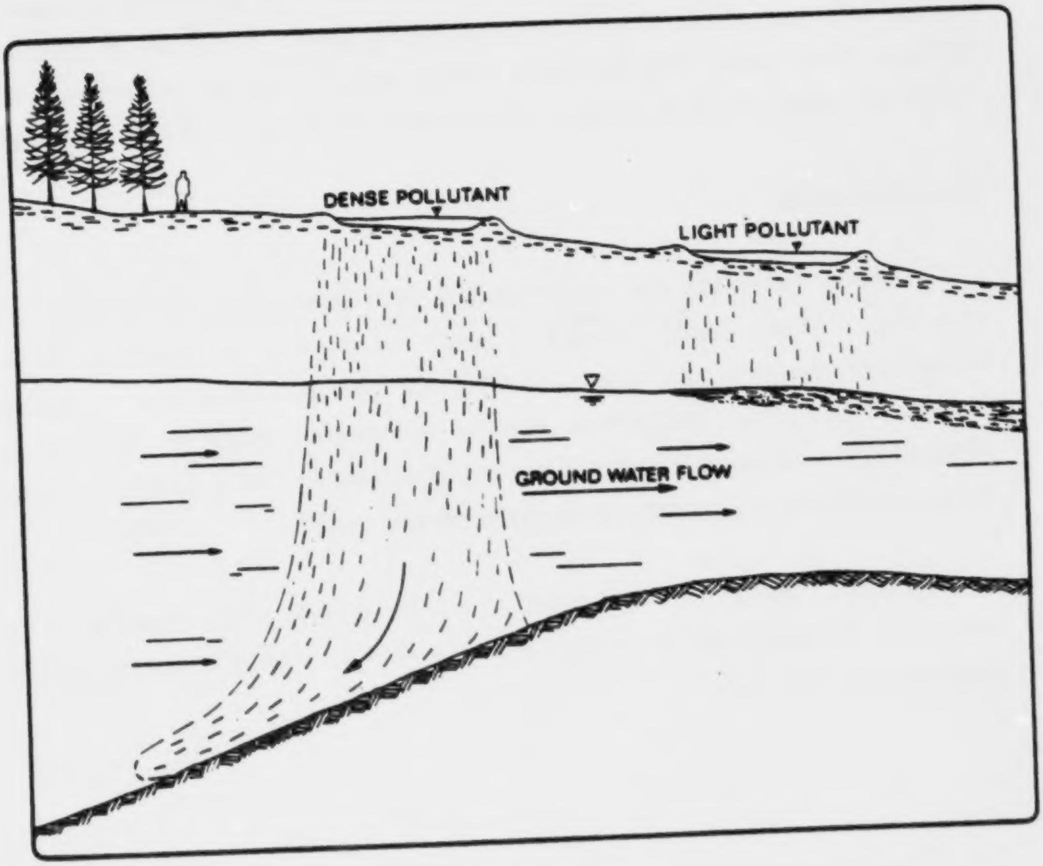

DENSE POLLUTANT
LIGHT POLLUTANT
GROUND WATER FLOW

Figure 15-15. Behavior of Immiscible Liquids of Different Densities in a Complex Ground Water Flow Regime

CASE STUDY 8: PERFORMING A SUBSURFACE GAS INVESTIGATION

Points Illustrated

- Design of a phased monitoring program to adequately characterize the extent and nature of a subsurface gas release.
- The use of ambient air and basement monitoring to supplement monitoring well data.
- The importance of subsurface characterization prior to design of a monitoring network.

Introduction

Gases produced in a landfill will migrate through the path of least resistance. Subsurface, lateral migration of landfill gas can occur due to natural and man-made barriers to vertical gas migration, such as impermeable overlying soil layers, frozen soil, or surface water. Installation of a gas-monitoring well netweork, in conjunction with sampling in buildings in the area, can be used to determine the need for corrective measures.

Facility Description

The unit in question is a landfill covering approximately 140 acres and bordered by a river on one side and a floodwall on the other. Beyond the floodwall lies a residential area (Figure 15-16). Several factors contribute to the subsurface gas migration problem at this landfill. The site reportedly received large quantities of organic wastes, which, when decomposed in the absence of air, produce methane and carbon dioxide gases. The presence of "tight", low permeability soils at the ground surface (12 feet of clayey silt at the surface grading to coarse sand and gravel at a depth of 55 feet) in the residential area combined with a rapidly rising water table below the landfill due to increased infiltration, restrict the vertical area available for gas migration and encourage lateral movement.

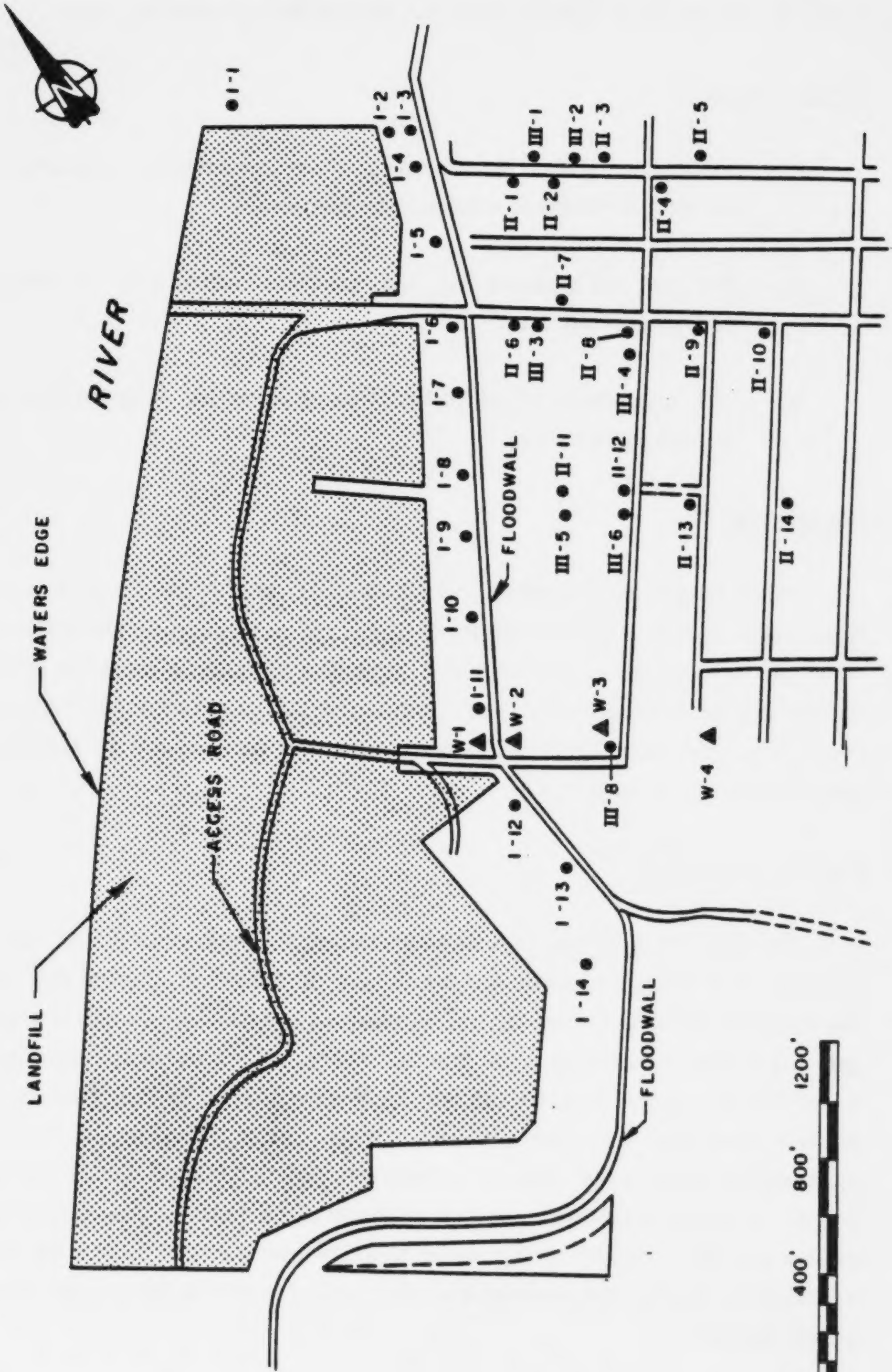

RIVER
WATERS EDGE
LANDFILL
ACCESS ROAD
FLOODWALL
FLOODWALL
I-1
I-2
I-3
I-4
I-5
I-6
I-7
I-8
I-9
I-10
I-11
I-12
I-13
I-14
II-1
II-2
II-3
II-4
II-5
II-6
II-7
II-8
II-9
II-10
II-11
II-12
II-13
II-14
III-1
III-2
III-3
III-4
III-5
III-6
III-8
W-1
W-2
W-3
W-4
0
400'
800'
1200'

Figure 15-16. Site Plan

Investigation of the gas migration began when foul odors and explosive levels of methane (5 to 15 percent by volume in air) were discovered in the basement of a home approximately 200 feet from the landfill. Residents in the area were evacuated, a sampling network was installed, and monitoring was conducted.

Sampling Program

The sampling was conducted in four phases, an initial screening phase and a more detailed three-phase sampling program. The monitoring network for the initial screening phase consisted of four wells (W1 through W4) aligned perpendicular to the long axis of the landfill, in the direction of (and extending beyond) the house where the gas was initially detected (Figure 15-16). The wells were drilled to an approximate depth of 30 feet below the land surface with the farthest well located about 1000 feet from the landfill boundary. These wells were sampled twice a day for a month. Samples were analyzed for methane and combustible hydrocarbons. The results of this initial monitoring showed average methane levels to be highest at the monitoring well located closest to the landfill (30 percent by volume), and roughly grading to below the detection limit at the well farthest from the landfill.

Grab and composite ambient air samples were also taken at the landfill and around houses in the neighborhood where gas was detected during the initial monitoring phase. These samples were analyzed for methane and other combustible hydrocarbons. No gases were detected above normal background levels in any of these above ground samples.

The next phase of monitoring (Phase I of the detailed sampling) involved the installation of 14 new gas monitoring wells (I-1 through I-14 in Figure 15-16). Most of these were placed in a line 250 feet from and parallel to the langitudinal axis of the landfill. Seven of these wells were drilled to an average depth of 55 feet, at least 5 feet below the water table so that ground water levels could be monitored. The other seven wells averaged 30 feet and did not intercept ground water. As shown in Figure 15-17, each well consists of three separate gas monitoring probes at evenly spaced depth intervals. Each probe was packed in gravel to allow gas to collect in its vicinity. Clay plugs were installed between each probe interval and

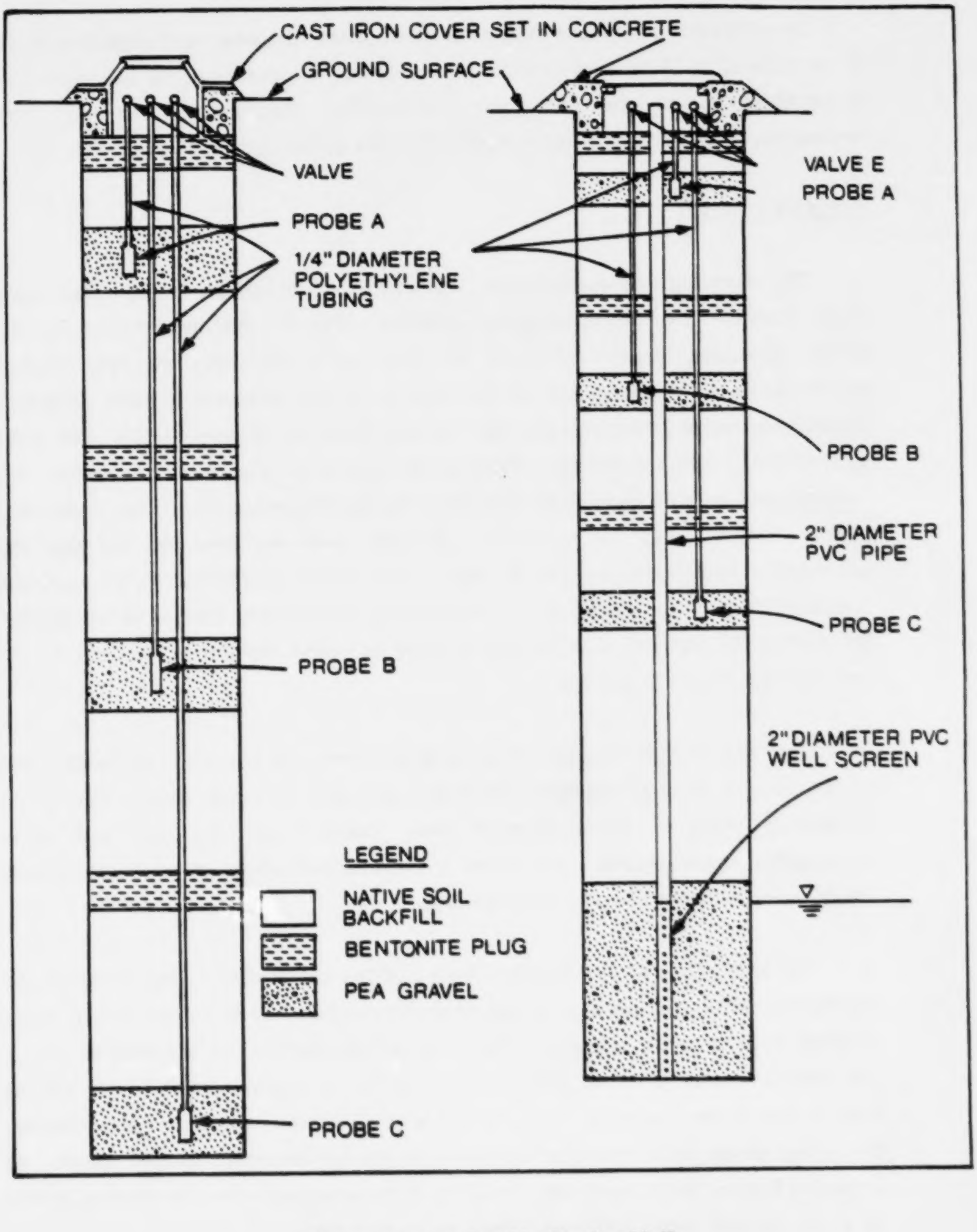

CAST IRON COVER SET IN CONCRETE
GROUND SURFACE
VALVE
PROBE A
1/4" DIAMETER POLYETHYLENE TUBING
PROBE B
PROBE C
VALVE E
PROBE A
PROBE B
2" DIAMETER PVC PIPE
PROBE C
2" DIAMETER PVC WELL SCREEN
LEGEND
NATIVE SOIL BACKFILL
BENTONITE PLUG
PEA GRAVEL

Figure 15-17. Gas Monitoring Well

between the top probe and the surface to minimize vertical movement of gas in the well. After two months of monitoring the well headspace twice monthly, concern over the high levels of methane that were being measured prompted an expansion of the monitoring well system.

The Phase II monitoring network involved another 14 wells (II-1 through II-14) installed to a depth of 6 feet along three radial lines from the landfill. These wells were monitored twice monthly with the Phase I wells. Methane was not detected at these wells because they were not deep enough to penetrate the clayey silt layer which in this area extended to a depth of 12 feet below the surface. Had adequate boring logs been compiled prior to the placement of these wells, the time and money involved in their installation and sampling could have been saved.

Detailed soil boring logs were compiled during the installation of the Phase III wells (III-1 through III-8 in Figure 15-16). These wells were drilled to ground water, averaging 55 feet in depth, were located in the vicinity of the Phase II wells, and were constructed in the same manner as the Phase I wells, with three gas probes placed in each well. The Phase III wells were located from 510 to 900 feet from the landfill. These wells were monitored twice a month for two months concurrently with the Phase I wells. Methane levels at all but two Phase III wells (which are located along the same radial line) exhibited explosive concentrations, ranging up to 67 percent by volume in air. These high concentrations of gas prompted another round of sampling of homes in the vicinity of wells exhibiting high methane concentrations.

Methane and combustible hydrocarbons were measured in basements, crawl spaces, and living areas of 28 homes adjacent to the landfill. All proved to be well below the lower explosive limit of methane.

Wells were then selected based upon proximity to houses exhibiting the highest levels of combustible gases, and samples to determine gas composition and concentration. The proportions of constituents in the collected gas was similar in all samples analyzed, and concentrations decreased with increasing distance from the landfill.

Ambient air sampling for organic gases at the landfill and in the residential area was also performed at this time and showed low levels of several organic compounds. Air samples collected in houses near the landfill showed the presence of two of the gas components measured in the test wells (methane and ethane).

The gas migration hazard had been sufficiently characterized so that a plan for corrective measures could be developed. This involved the installation of 31 gas extraction wells which were located along a line between the landfill and the residential areas, and a blower system to "pump" the gas out of these extraction wells.

Results

The monitoring program implemented for this case was, for the most part, effective in characterizing the extent and concentrations of subsurface gas contamination. The four initial monitoring wells verified that the landfill was the source of contamination. Phase I monitoring confirmed that the high levels of methane were present at all depths monitored and along the entire length of the landfill. The horizontal location of the Phase II wells, in lines radiating from the landfill, was appropriate, although the lack of subsurface characterization rendered them useless. Phase III sampling established the vertical and lateral extent of subsurface contamination into the residential area.

Throughout the study, ambient air sampling as well as monitoring of homes in the area of concern provided adequate safety control, as well as an additional indication of potential migration of landfill-generated gases.

Case Discussion

Subsurface gas migration can occur when atmospheric ventilation of gases generated in a landfill is insufficient. The gas produced migrates along the paths of least resistance. Conditions restricting release to the atmosphere such as saturated or tight surficial soils may force the gas to move laterally over considerable distances.

This case was selected an an illustration of a phased approach to monitoring a subsurface gas release. The results of one phase of monitoring were incorporated into the design of the next phase throughout the study. Monitoring was performed at discrete vertical levels below the surface and at distances from the landfill that were adequate to confirm the extent of the contaminant plume.

The study also illustrates the importance of characterizing subsurface conditions prior to installing monitoring wells. Fourteen unusable wells were installed and then monitored for two months because of insufficient preliminary soil (stratigraphic) characterization.

The use of ambient and basement monitoring for gas to supplement monitoring well data is also noted in this case study. The location of new wells can be based in part on readings from these sources.

CASE STUDY 9: USE OF THE SUBSURFACE GAS MODEL IN ESTIMATING GAS MIGRATION AND DEVELOPING MONITORING PROGRAMS

Point Illustrated

- Predictive models can be used to estimate the extent of gas migration from a suspected subsurface source. This information can be used to estimate human exposure and to determine appropriate locations for monitoring wells and gas collection systems.

Introduction

Methane is a common landfill gas and is often used as an indicator of landfill gas migration. The subsurface methane predictive model, described in Volume III, Appendix F of this document, will yield a methane concentration contour map and predict the distance that methane will migrate. The model consists of a series of charts developed by imposing a set of simplifying assumptions on a general methane migration computer model.

A methane migration distance prediction chart is used to find a preliminary migration distance based on the age of the site and the soil type. The remaining charts are used to find correction factors which are in turn used to adjust the migration distance. These factors are based upon site characteristics, e.g., depth of the waste.

Facility Description

The unit is located on a 583-acre site in a suburb of a major metropolitan area. Figure 15-18 shows the site layout. The landfill itself occupies 290 acres. 140 acres of the landfill were used for the disposal of hazardous wastes. Both hazardous and nonhazardous wastes were disposed at the site from 1968 to 1984. Hazardous waste disposal ended in 1984. The disposal of sewage treatment sludges and municipal refuse continues. As seen in Figure 15-18, residential development has taken place with houses now bordering the facility to the south. A population of 30,000 to 40,000 people reside within a mile radius of the landfill center.

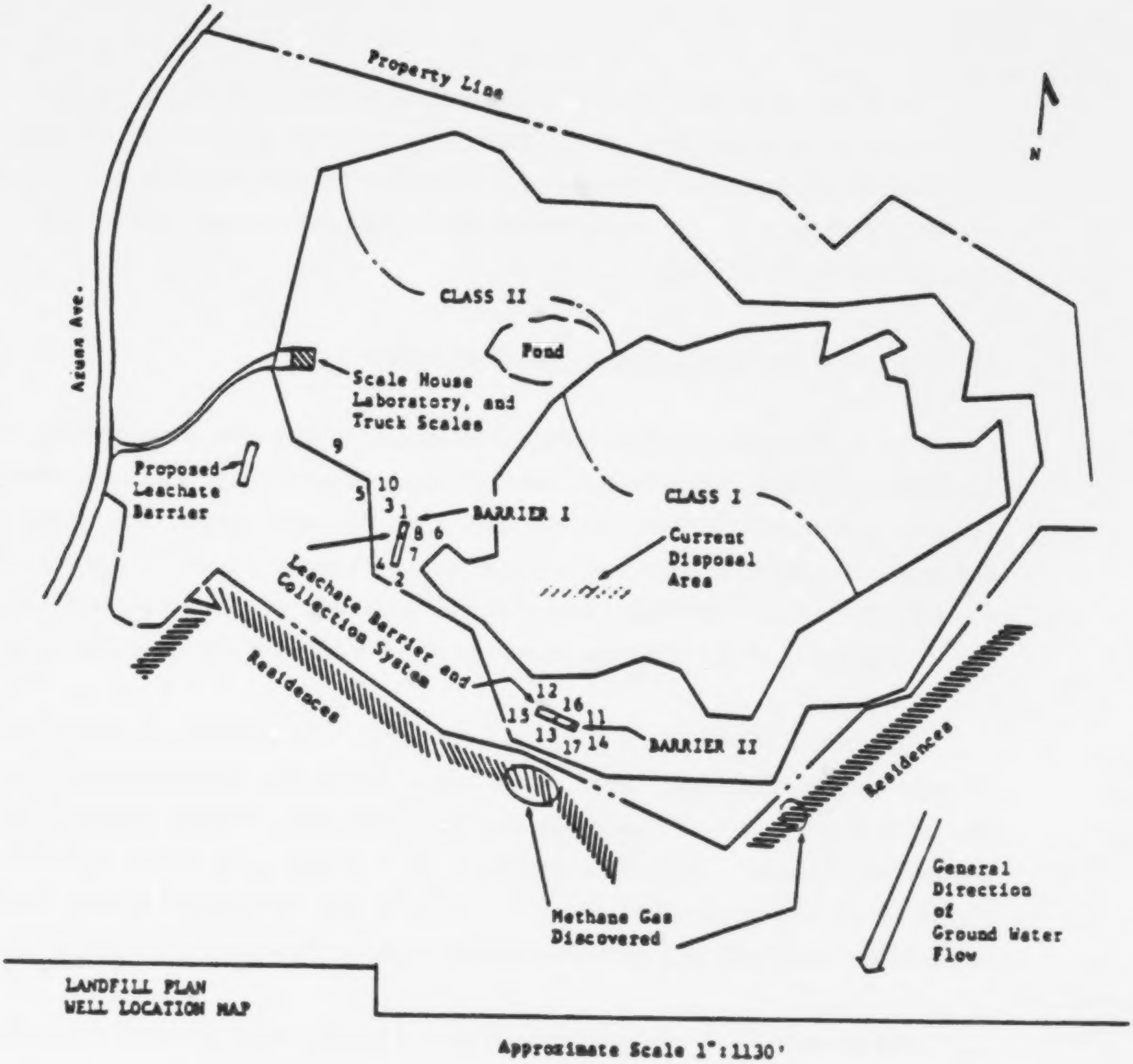

Property Line
N
Azusa Ave.
CLASS II
Pond
Scale House
Laboratory, and
Truck Scales
Proposed
Leachate
Barrier
9
10
5
3
1
BARRIER I
8
6
7
4
2
CLASS I
Current
Disposal
Area
Leachate Barrier and
Collection System
Residences
12
16
15
11
13
17
14
BARRIER II
Residences
Methane Gas
Discovered
General
Direction
of
Ground Water
Flow
LANDFILL PLAN
WELL LOCATION MAP
Approximate Scale 1":1130'

Figure 15-18. Facility Map

The unit is a V-shaped fill overlying sediment and bedrock. The rock type is a poorly consolidated, fractured sandy silt offering no lithologic barrier to gas migration. The shape of the water table has not been established. Also unknown are the possible effects of local, permeable formations such as sand lenses, faults, etc.

The warm climate at the site encourages rapid degradation of organic wastes and therefore rapid gas production. Site characteristics suggest that vertical gas migration is not hindered. However, the compaction of the fill cover by truck traffic combined with the rapid production of gas has forced lateral migration through the fractured sandy silt.

Applying the Subsurface Methane Predictive Model

The subsurface methane predictive model allows the development of a subsurface methane concentration contour map. The model predicts the distance methane will migrate from a unit based on its age, depth, soil type, and environmental factors. A contour map for two different methane concentrations, 5 and 1.25 percent, is predicted. The likelihood of human exposure can be estimated from the location of the contours with respect to on site and off site structures.

Application of the model involves three steps. The first step is the prediction of gas migration distances, based on the age of the landfill and the local soil type. The unit of interest is 18 years old and has sandy soils. Figure 15-19 shows the uncorrected methane migration distances for various soils over time. From Figure 15-19, the uncorrected migration distances for the subject site are 165 feet and 255 feet for 5 and 1.25 percent methane concentrations, respectively.

The second step in applying the model involves the application of a correction factor to the migration distances based on waste depth. The deeper the waste, the greater the opportunity for subsurface migration. Figure 15-20 is used to find the correction factors for depth. For the subject waste unit the depth is 25 feet, which corresponds to a correction factor of 1.0 for both concentrations.

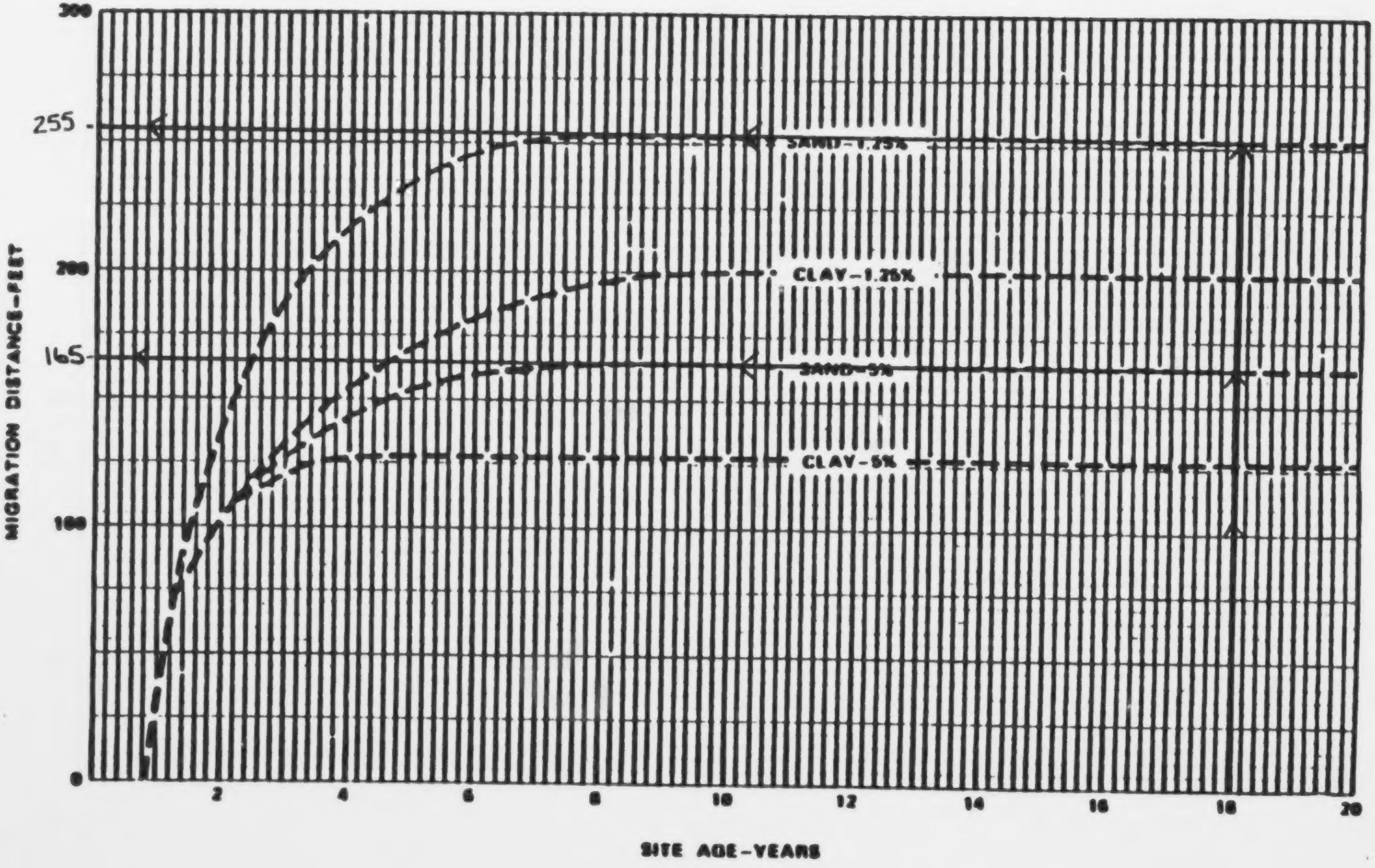


Figure 15-19. Uncorrected Migration Distances for 5 and 1.25% Methane Concentrations

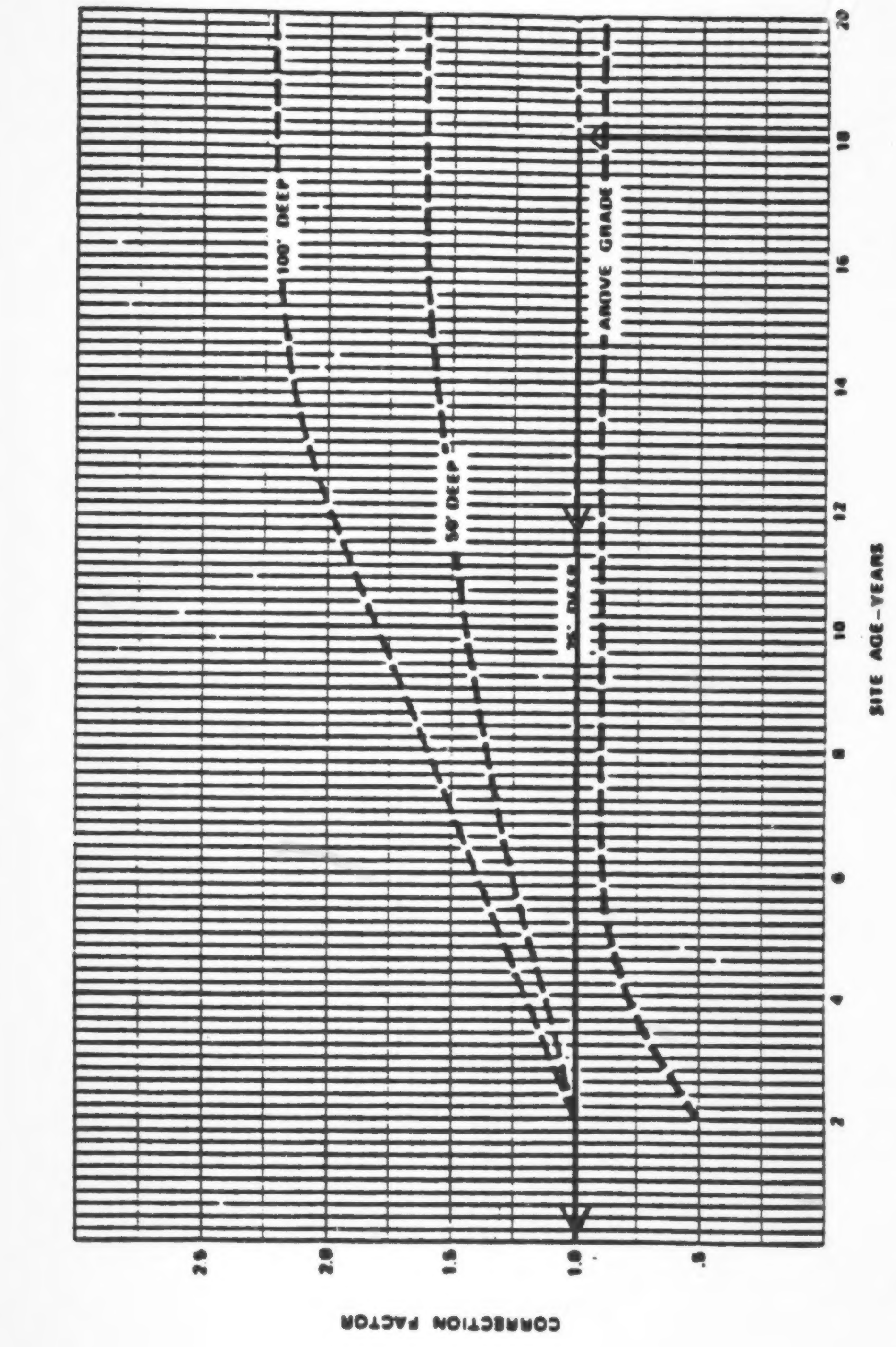


Figure 15-20. Correction Factors for Landfill Depth Below Grade

The final step in applying the model is the correction of migration distances based on surface venting conditions. The following equation is used to calculate the venting correction factor, ACF:

$$ACF = [(ICF-1)(\text{fraction of site which is impermeable})] + 1 \qquad (1)$$

The impervious correction factor, ICF, is obtained from Figure 15-21. In the above equation, ICF is adjusted to account for the fraction of time the solid is saturated or frozen and the fraction of the land area that is impermeable due to natural or man-made barriers. If corrections for both time and area are required, the fractions are additive. From Figure 15-21, the ICF for a unit 18 years old and 25 feet deep is 2.4. Site charcteristics together with weather conditions indicate a value of 0.4 for the fraction of impermeable area. Substituting these values into equation 1 yield an adjusted correction factor of:

$$ACF = [(2.4-1)(0.4)] + 1 = 1.56.$$

Results

Table 15-2 summarizes the results from steps one through three of the model application. The predicted migration distances for methane are found by multiplying the uncorrected distance from step one by the correction factors from steps two and three. The predicted distances of travel for methane are 255 feet and 395 feet for 5 and 1.25 percent concentrations, respectively.

Table 15-2

MODEL RESULTS

Methane Concentration (percent)	Uncorrected Distance (feet)	Correction for Depth	Correction for Venting	Corrected Distance (feet)
5	165	1.0	1.56	255
1.25	255	1.0	1.56	395

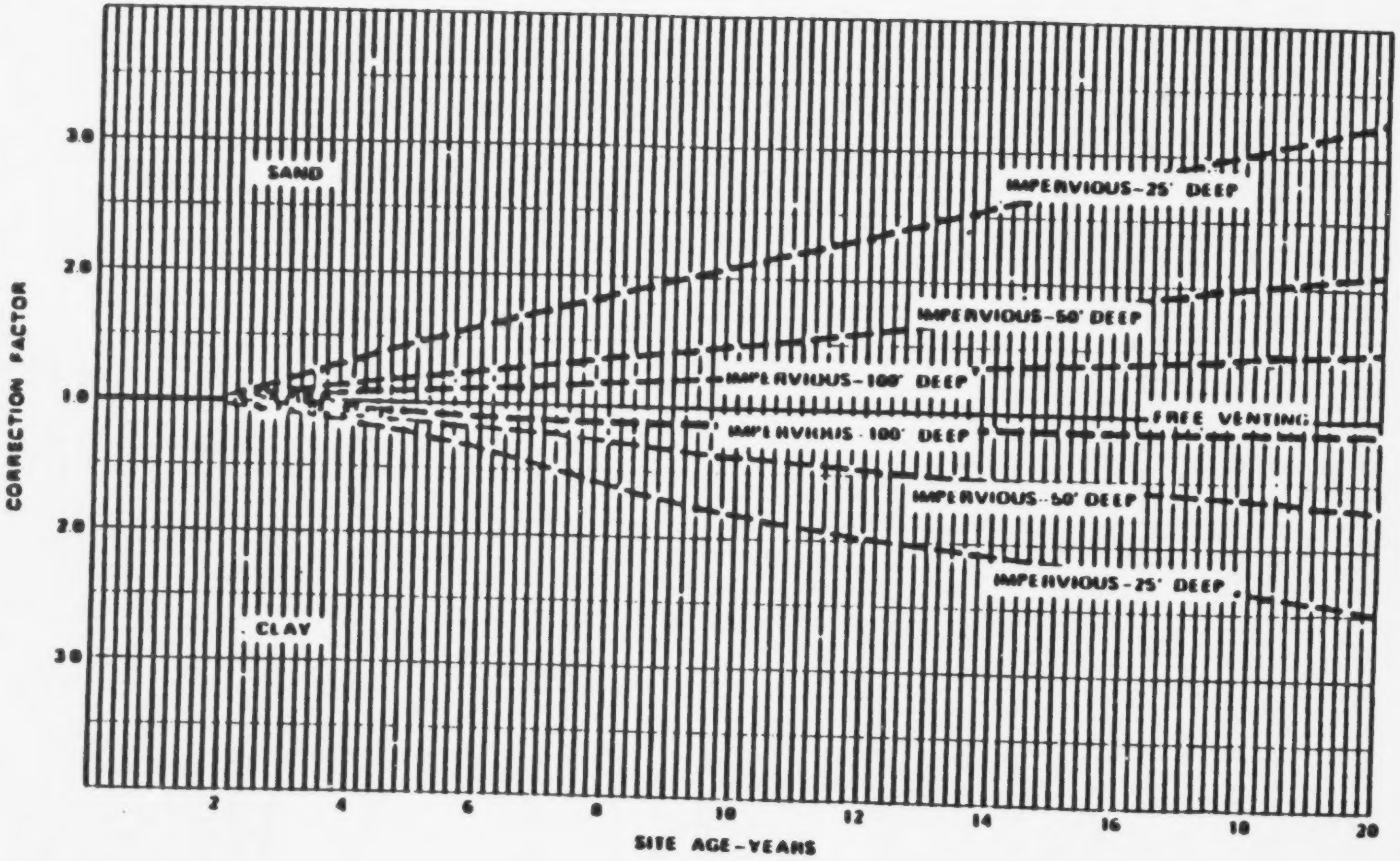


Figure 15-21. Impervious Correction Factors (ICF) for Soil Surface Venting Condition Around Landfill

Case Discussion

Figure 15-22 is a methane concentration contour map developed from the predicted travel distances. The map indicates that the possibility of human exposure to landfill gas is high. Landfill gas is known to be present and well drilling operations at the landfill have caused minor explosions. The monitoring wells along the facility perimeter and testing in nearby homes indicate that gas has migrated off site. The contour for both the 5 percent and 1.25 percent methane encloses homes evacuated because of gas accumulation. Measures have been taken to mitigate the immediate problems and the landfill operators have installed additional gas collection wells and extended the monitoring system.

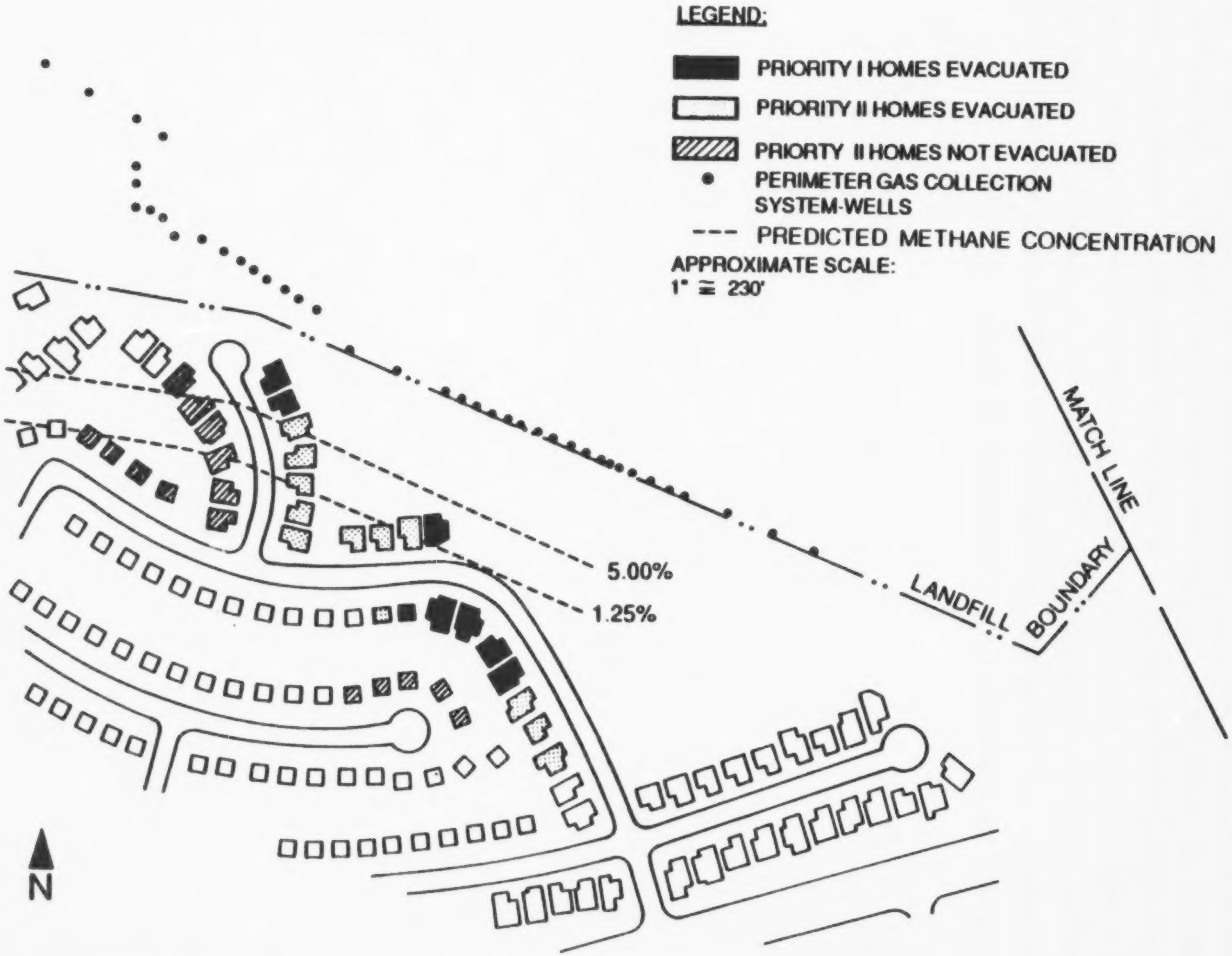

LEGEND:
PRIORITY I HOMES EVACUATED
PRIORITY II HOMES EVACUATED
PRIORTY II HOMES NOT EVACUATED
PERIMETER GAS COLLECTION SYSTEM-WELLS
PREDICTED METHANE CONCENTRATION
APPROXIMATE SCALE:
1" ≅ 230'
MATCH LINE
LANDFILL BOUNDARY
5.00%
1.25%
N

Figure 15-22. Landfill Perimeter Gas Collection System-Wells

CASE STUDY 10: DESIGN OF A SURFACE WATER MONITORING PROGRAM

Point Illustrated

- When designing a surface water monitoring program, site-specific sediment and suspended solids information should be considered.

Introduction

Designing a surface water monitoring program to determine the extent of contamination involves identifying the potential waste sources, the contaminants likely to be present in each waste stream, and the flow paths by which the contaminants could reach surface waters. The fate of the contaminants once they reach the surface water must also be considered when selecting sampling stations and parameters to be measured. The example described here illustrates the design of a monitoring program for a river system.

Facility Description

A facility which processed zinc, copper and precious metals from ores operated along a river for five years. The plant was closed after being cited for repeated fish kills which were reportedly due to failures of a tailings pond dike. At present, the site is covered with tailings containing high concentrations of copper, zinc, cadmium, arsenic and lead. There is no longer a tailings pond.

Site Setting

The site is located on coarse colluvium (hill-slope deposits of weathered bedrock) and fine-grained alluvium. These deposits are typically 50 feet thick. Metamorphic rock (phyllite) underlies the unconsolidated materials. Ground water moves laterally in the gravel formations from the steep valley walls toward the river.

The site is about 400 feet from the river. Two drainage ditches cross the lower portion of the site and merge prior to leaving the site. The ditch carries the combined flow and discharges directly into the river (Figure 15-23). No other tributaries enter the river within 2 miles of this location.

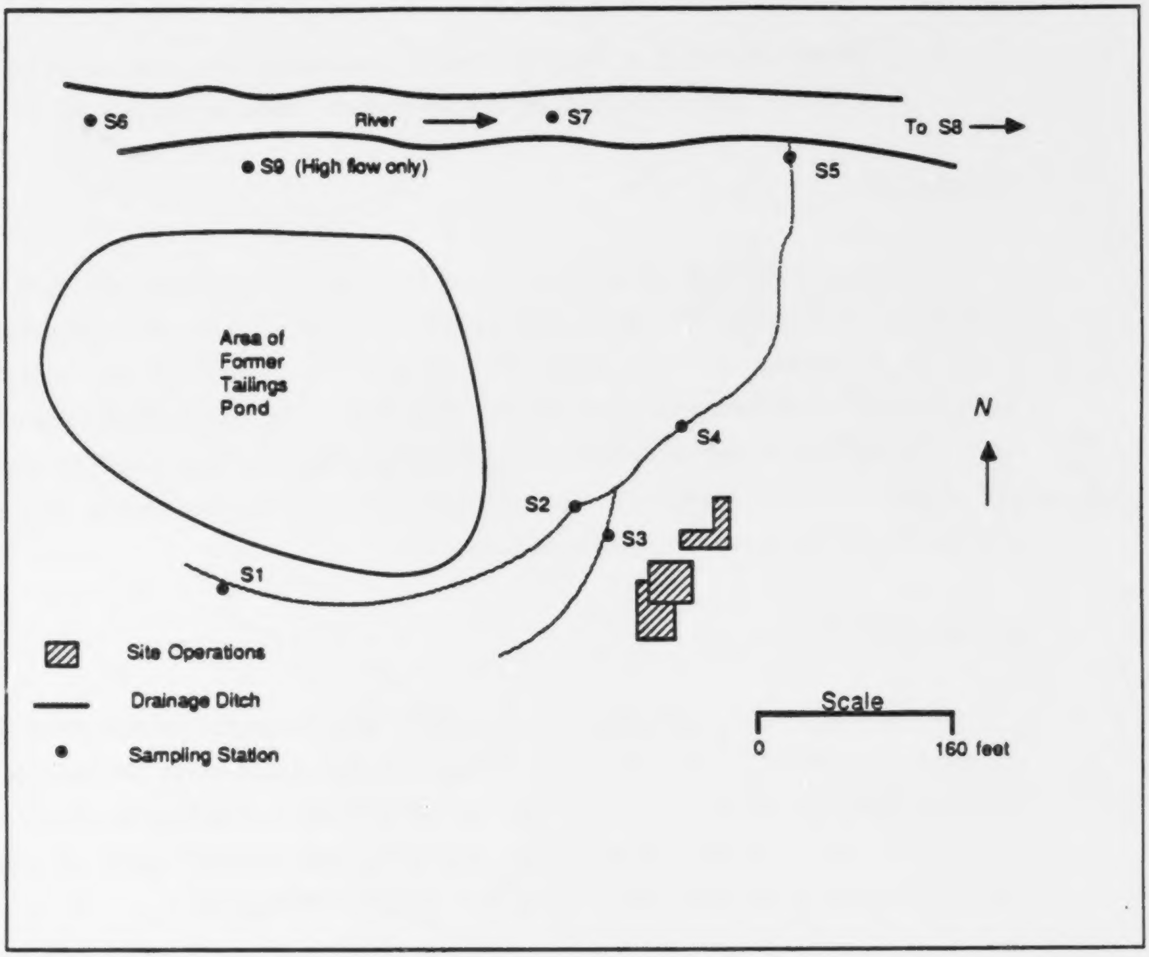

S6
River
S7
To S8
S9 (High flow only)
S5
Area of Former Tailings Pond
N
S4
S2
S3
S1
Site Operations
Drainage Ditch
Sampling Station
Scale
0
160 feet

Figure 15-23. Sampling Station Locations for Surface Water Monitoring

Sampling Program

A surface water monitoring program was designed as part of the Phase I remedial investigation to determine the extent of contamination in the river. Existing data from a reconnaissance visit had shown high concentrations of metals in the drainage ditch sediments (e.g., 5,170 mg/kg Cu and 11,500 mg/kg Zn). Ground water data from the plant's well showed detectable concentrations of Cu (7 µg/l) and Zn (54 µg/l). The ground water concentrations were below drinking water standards but were only slightly above levels of concern for aquatic life (5.6 µg/l for Cu and 47 µg/l for Zn, U.S. EPA, 1976). Actual differences are within the limits of analytical error. In any case, the contribution of metals to the river by ground water seepage at the site was small and considered negligible.

Based on a review of the plant history and the available water quality and sediment data, a monitoring program was designed. The potential pathways by which metals could reach the river appeared to be direct discharge from the drainage ditch, seepage of contaminated ground water, and storm water runoff. Plant records indicated that typical flows in the drainage ditch at its confluence with the river varied from 1 to 3 cubic feet per second (cfs) in the spring. During extreme flood conditions, the flow in the ditch exceeded 20 cfs. In the summer, flows in the drainage ditches at all locations were less than 0.5 cfs. Resuspension of contaminated sediments in the ditches during storm runoff appeared to be the most likely pathway for metals to reach the river. The specific metals of concern were identified as As, Cd, Cu, Pb and Zn based on the processes used at the plant and the composition of the ores which contained some arsenopyrites (As, Cu), galena (Pb), and sphalerite (Zn, Cd).

The available soil and water quality data from the reconnaissance visit were reviewed to determine the likely fate of the metals. Soils in the area were circumneutral (pH = 6.5) and contained about 0.5 percent organic matter by weight. Thus the metals, particularly Pb, would be expected to adsorb onto the soil particles. In the on-site tailings piles, the pH of core samples ranged between 3.3 and 4.9. Low soil pH values had been measured in sediments in the drainage ditch just downgradient of the tailings pile. The pH of the river during the reconnaissance was 6.9. The suspended solids concentration was 10 mg/l.

Estimates of the distribution of metals between the dissolved and adsorbed phases for a range of partition coefficients (K_p) are shown in Table 15-3. For example, if $K_p = 10^4$ and the suspended solids concentration was 10 mg/l, 90 percent of the metal present would be in the dissolved phase. This information indicated that even though a metal (e.g., lead), was known to sorb strongly, a significant amount could be transported in the dissolved phase. Thus, both water and suspended solids should be analyzed for metals. The complete list of parameters selected for measurement in the Phase I investigation and the rationale for their selection are outlined in Table 15-4.

The sampling stations were selected to determine river quality up and downstream of the site and to determine whether particulates with sorbed metals were deposited on the river banks or streambed. The sampling stations and the rationale for their selection are listed in Table 15-5. The station locations are shown in Figure 15-23. Because floods were considered to be one cause of contamination incidents, samples were to be collected under both high and low flow conditions.

Selected results of the surface water quality sampling program for spring conditions are given below:

Station	Dissolved Copper Concentration, μg/l
S5 (mouth of ditch)	1110
S7 (upstream)	2.7
S8 (downstream)	4.0

TABLE 15-3

RELATIONSHIP OF DISSOLVED AND SORBED PHASE POLLUTANT CONCENTRATIONS TO PARTITION COEFFICIENT AND SEDIMENT CONCENTRATION

K_p	S (ppm)	C_W/C_T[a]	If C_T = 100 ppb		
			C_W =	X =	C_S =
10^0	1	1.0	100.	100.	0.0
	10	1.0	100.	100.	0.0
	100	1.0	100.	100.	0.0
	1000	1.0	100.	100.	0.0
	10000	1.0	99.	99.	1.0
10^1	1	1.0	100.	1×10^3	0.0
	10	1.0	100.	1×10^3	0.0
	100	1.0	99.9	999.	0.1
	1000	1.0	99.0	990.	1.0
	10000	0.9	90.9	909.	9.1
10^2	1	1.0	100.	1×10^4	0.0
	10	1.0	99.9	1×10^4	0.1
	100	1.0	99.0	9.9×10^3	1.0
	1000	0.9	90.9	9.1×10^3	9.1
	10000	0.5	50.	5×10^3	50.
10^3	1	1.0	99.9	1×10^5	0.1
	10	1.0	99.0	9.9×10^4	1.0
	100	0.9	90.9	9.1×10^4	9.1
	1000	0.5	50.	5×10^4	50.
	10000	0.1	9.1	9×10^3	90.9
10^4	1	1.0	99.0	9.9×10^5	1.0
	10	0.9	90.9	9.1×10^5	9.1
	100	0.5	50.	5×10^5	50.
	1000	0.1	9.1	9.1×10^4	90.9
	10000	0.0	1.0	9.9×10^3	99.0

After Mills *et al.*, 1985.

[a] The fraction dissolved (C_W/C_T) is calculated as follows:

$$\frac{C_W}{C_T} = \frac{1}{1 + K_p \times 5 \times 10^{-6}}$$

here Kp = partition coefficient, ℓ/kg

SS = suspended solids concentration, mg/ℓ

TABLE 15-4

PARAMETERS SELECTED FOR SURFACE WATER MONITORING PROGRAM

Parameters	Rationale
Metals - As, Cd, Cu, Pb, Zn	Determine extent of contamination
pH	Needed to predict sorption behavior, metal solubility, and speciation
Dissolved Oxygen, Sulfide, Fe(II), Fe(III)	Needed to determine redox conditions which influence behavior of metals, particularly the leaching of tailings
Alkalinity	A measure of how well buffered a water is; allows consideration of the likelihood of pH change
Total Dissolved Solids	Used as a water quality indicator and for QA/QC checks
Major Cations (Ca^{2+}, Mg^{2+}, Na^+, K^+, NH^+_4) Major Anions ($C1^-$, SO_4,$^{2-}$ NO_3^-)	May identify other waste sources; can influence fate of trace metals
Suspended Solids	Needed to predict the fraction of metal in water which is sorbed
Streamflow	Needed to compute mass balances and assist in identifying sources of observed contamination

TABLE 15-5

SELECTED SURFACE WATER MONITORING STATIONS AND RATIONALE

Station	Media	Rationale
Drainage ditch west of site (S1)	Water and sediments	Deterine whether off-site drainage is significant source of contamination
Drainage ditches on site (S2 and S3)	Water and sediments	Identify on-site sources
Downstream of confluence of 2 ditches (S4)	Water and sediments	Provide information for checking mass balances from the 2 drainage ditches
Mouth of drainage ditch (S5)	Water, suspended sediment, bedload	Determine upstream water quality
River (S6, S7, and S9)	Water, suspended sediment, bedload	Determine upstream water quality
River (S8)	Water, suspended sediment, bedload	Determine quality downstream of site and provide data for mass balance

A mass balance was computed to determine how much of the apparent decrease from the ditch (S5) to the downstream river sampling point (S8) was due to dilution and how much could be attributed to other processes (e.g., sorption, precipitation). The concentration in the river considering dilution alone was predicted using the following mass balance equation:

$$C_R = \frac{C_u Q_u + C_w Q_w}{Q_u + Q_w}$$

where

C_R = downstream concentration of pollutant in river following mixing with ditch waters (S8), µg/l

C_w = concentration in ditch water (S5), µg/l

C_u = concentration in river above ditch (S7), µg/l

Q_w = discharge rate of ditch, ft^3/sec

Q_u = flow rate of river above ditch, ft^3/sec.

At the time of sampling, the flow in the ditch at station S5 was 1 cfs and the river flow at station S7 was 155 cfs. Using the above equation, the predicted river concentration for Cu ws 10 µg/l. (The observed concentration was 4 µg/l.) The observed decrease in concentration was primarily due to dilution, although other attenuation processes (e.g., sorption) obviously were occurring. Next, an estimate of the expected sorbed concentration was made as follows:

$$X = K_p C$$

where

X = sorbed concentration, µg/kg
K_p = partition coefficient, l/kg
C = concentration of dissolved phase, µg/l

Here, the sorbed concentration of Cu was estimated as 8×10^5 µg/kg (800 mg/kg).

Case Discussion

This case illustrates the use of site-specific data and the use of information on the environmental fate of contaminants in the design of a surface water monitoring program. Site data are needed to locate waste sources and to determine the likely flow paths by which contaminants reach rivers. An understanding of the general behavior of the contaminants of interest and of the factors which influence their fate is helpful in determining where samples should be collected and what parameters, particularly master variables, should be measured. Collecting data on such parameters (e.g., pH, suspended solids) ensures that the necessary information is available to interpret the data.

CASE STUDY 11: USE OF BIOASSAYS AND BIOACCUMULATION TO ASSESS POTENTIAL BIOLOGICAL EFFECTS OF HAZARDOUS WASTE ON AQUATIC ECOSYSTEMS

Point Illustrated

- Measurements of toxicity (i.e., bioassays) and bioaccumulation can be used to assess the nature and extent of potential biological impacts in off-site areas.

Introduction

A study was conducted to determine whether leachate discharged into surface waters had adversely affected biota in a stream adjacent to a waste site and in a nearby lake. The components of the study included chemical analyses of the leachate, surface waters, sediments, and tissue samples; toxicity testing of the surface waters; and surveys of the structure and composition of the biological communities. Tissue analyses are important for determining contaminant bioaccumulation, and assessing potential human exposure through consumption of aquatic organisms. Toxicity testing is important for determining contaminant bioaccumulation, and assessing potential human exposure through consumption of aquatic organisms. Toxicity testing is important for determining potential lethal and sublethal effects of contaminant exposure on aquatic biota. Although ecological analysis of community structure and composition is also an important component of biomonitoring, it will not be discussed here since the focus is on the relationships between the leachate source, the distributions of contaminants near the waste site, and the toxic effects and bioaccumulation of the contaminants in the tissues of local fauna.

Site Description

The five-acre facility is an industrial waste processing site which accepts wastes from nearby plastic manufacturing and electroplating industries. Liquid wastes are dewatered on site prior to removal to an off-site disposal area. The principal wastes processed at the faclity include several organic compounds and metals.

The site contains a waste water impoundment with numerous seeps and draining channels that transport leachate into an adjacent river (Figure 15-24). The river flows from northeast to southwest, and is joined by a tributary stream before entering a nearby lake. The RFA indicated an oily sheen associated with a strong chemical odor on the surface of the stream below the treatment pond, and further reported numerous violations of the NPDES permit. Subsequent analyses of samples taken from the drainage channels and seeps flowing into the river showed high concentrations of organic and trace metal contaminants, principally bis (2-ethylhexyl) phthalate, ethylbenzene, phenol, copper, cadmium, and zinc.

Sampling Program

Six stations were sampled to assess possible toxicity and bioaccumulation of released substances (Figure 15-24). Station 6, located upstream from the release, was selected as a reference location for the stream. Station 17 was selected as a reference location for the lake since it is located away from the river mouth and because prevailing winds from the northwest direct the river discharge along the southeast shore of the lake away from the station. Stations 7, 15, and 18 were selected to determine the extent of toxic impacts on river and lake biota.

Water, sediments, and tissues of bottom-dwelling fishes (brown bullhead catfish, Ictalurus nebulosus) were collected at each station. Concentrations of bis(2-ethylhexyl) phthalate, ethylbenzene, phenol, copper, cadmium, and zinc were measured in each matrix. Analyses were conducted according to U.S. EPA guidelines for sediments, water, and tissues. Water quality variables (dissolved oxygen, temperature profiles, and alkalinity), total organic carbon in sediments, and lipid content of tissues were also measured.

Three independent bioassays were conducted on each water sample. The test species and endpoints used in the bioassays were those recommended in the U.S. EPA protocol for bioassessment of hazarduos waste sites (Tetra Tech, 1983). Growth inhibition in the alga Selanastrum capricornutum, and mortality in the crustacean Daphnia magna were determined using U.S. EPA (1985) short-term methods for chronic toxicity testing. Inhibition of enzyme-mediated luminescence

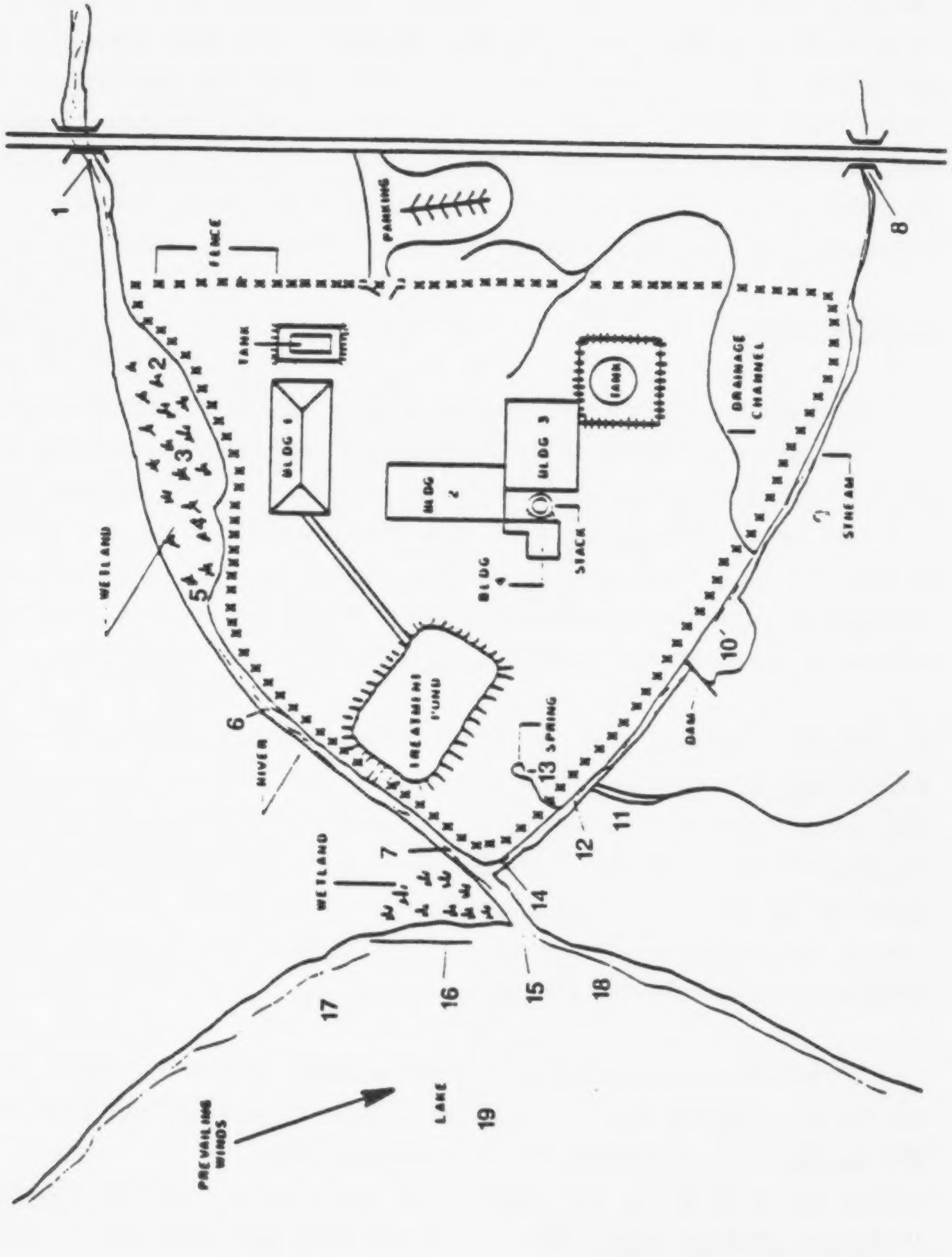

PREVAILING WINDS
LAKE
19
17
16
15
18
WETLAND
7
14
12
11
RIVER
6
SPRING
13
DAM
10
TREATMENT POND
BLDG 4
STACK
STREAM
9
WETLAND
5
4
3
2
BLDG 1
BLDG 2
BLDG 3
TANK
TANK
DRAINAGE CHANNEL
FENCE
PARKING
1
8

Figure 15-24. Site Plan and Water Sampling Locations

in the bacterium Photobacterium phosphoreum (i.e., the Microtox procedure) was measured according to the methods establish by Bulich et al. (1981).

Results

Results of the survey indicated that concentrations of organic contaminants in the surface waters were generally less than U.S. EPA water quality criteria, but that concentrations of inorganic contaminants generally exceeded water quality criteria at Stations 7, 15, and 18 (Table 15-6). In comparison with the reference stations, significant sediment contamination was evident at Stations 7, 15, and 18 for the three trace metals (Table 15-7). Tissue concentrations of organic substances exceeded detection limits for bis(2-ethylhexyl) phthalate at Stations 7 and 15, and for ethylbenzene at Station 7 (Table 15-8). However, trace metal concentrations in tissues were highly elevated at Stations 7, and 15, but only slightly elevated at Station 18.

The bioassay data showed a considerable range in sensitivity, with the algal bioassay being the most sensitive (Table 15-9). Consequently, the bioassay results were normalized to the least toxic of the reference stations (i.e., Station 6) in order to compensate for the wide range of sensitivity among the test species (Table 15-10). Overall, the bioassay results showed a high degree of agreement with contaminant concentrations in water and sediments (Figure 15-25, Table 15-6 and 15-7). Stations 7 and 15 were highly toxic, and Station 18 was moderately toxic. Only the algal bioassay indicated significant, but low, toxicity at Station 17 (the lake reference station).

In summary, the results indicated that the organic contaminants were less of a problem than the trace metals in terms of bioaccumulation and potential toxicity. Most of the observed toxicity was attributed to trace metal contamination which is consistent with the elevated concentrations of trace metals measured in the water, sediments, and tissues.

TABLE 15-6

MEAN CONCENTRATIONS (µg/ℓ) OF ORGANIC SUBSTANCES AND TRACE METALS IN LEACHATE AND SURFACE WATERS[a]

Chemical Class	Chemical	Station						Water Quality Criteria[b]	
		Seep L1	River 6	River 7	Lake 15	Lake 18	Lake 17	Acute	Chronic
Base Neutral	Bis (2-ethylhexyl) phthalate	600	2	11	10	1	2	940	3
Volatile	Ethylbenzene	100	1	1	<1	1	2	32000	NA[c]
Acid Extractable	Phenol	1500	<1	18.37	<1	<1	<1	10200	2560
Metals	Copper	4300	<1	489	56	26	2	18	12
	Zinc	35000	17	4290	1100	37	35	320	47
	Cadmium	4800	<1	146	49	<1	<1	3.9	1.1

[a] River and lake alkalinity = 100 mg CaCO3/L

[b] Trace metal criteria adjusted for alkalinity

[c] Not available for this substance

TABLE 15-7

MEAN SEDIMENT CONCENTRATIONS (μg/kg DRY WT) OF ORGANIC SUBSTANCES AND TRACE METALS

Chemical Class	Chemical	Station					
		Seep L1	River 6	River 7	Lake 15	Lake 18	Lake 17
Base Neutral	Bis (2-ethylhexyl) phthalate	NA[a]	216	1188	1080	108	216
Volatile	Ethylbenzene	NA	10	34	20	14	8
Acid Extractable	Phenol	NA	<30	<30	<30	<30	<30
Metals	Copper	NA	3	1663	190	88	7
	Zinc	NA	11	28314	7260	24	23
	Cadmium	NA	<0.1	19	6	<0.1	<0.1

[a] Not applicable (NA).

TABLE 15-8

MEAN LIVER TISSUE CONCENTRATIONS (μg/kg WET WT) OF ORGANIC SUBSTANCES AND TRACE METALS

Chemical Class	Chemical	Station					
		Seep L1	River 6	River 7	Lake 15	Lake 18	Lake 17
Base Neutral	Bis (2-ethylhexyl) phthalate	NA[a]	<25	95	86	<25	<25
Volatile	Ethylbenzene	NA	<5	9	<5	<5	<5
Acid Extractable	Phenol	NA	<30	<30	<30	<30	<30
Metals	Copper	NA	118	1600	750	237	180
	Zinc	NA	983	28400	8500	2139	1420
	Cadmium	NA	115	1600	639	190	125

[a] Not applicable (NA).

TABLE 15-9

MEAN LC50 AND EC50 VALUES (PERCENT DILUTION) FOR SURFACE-WATER BIOASSAYS[a]

Bioassay	Endpoint	Station					
		Seep L1	River 6	River 7	Lake 15	Lake 18	Lake 17
Algae	Growth inhibition (EC50%)[a]	NA[b]	>100[c]	0.4	10.0	24.9	75.0
Daphnia	Mortality (LC50%)[d]	NA	>100	3.3	18.5	100.0	90.0
Microtox	Decreased luminescence (EC50%)[a]	NA	>100	5.6	15.0	43.4	>100

[a] Percent dilution required corresponding to a 50 percent response

[b] Not applicable (NA) because leachate toxicity was not tested

[c] Response of >100 indicates that samples were not toxic at all dilutions tested

[d] Percent dilution corresponding to 50 percent mortality

TABLE 15-10
RELATIVE TOXICITY OF SURFACE-WATER SAMPLES[a]

Bioassay	Endpoint	Station					
		Seep L1	River 6	River 7	Lake 15	Lake 18	Lake 17
Algae	Growth inhibition (EC50%)	NA[b]	0.0	99.6	90.0	75.1	25.0
Daphnia	Mortality (LC50%)	NA	0.0	96.7	81.5	0.0	10.0
Microtox	Decreased luminescence (EC50%)[a]	NA	0.0	94.4	85.0	56.6	0.0

[a] Relative toxicity = 100 x [(Reference Station - Impacted Station)/Reference Station]

[b] Not applicable (NA) because leachate toxicity was not tested

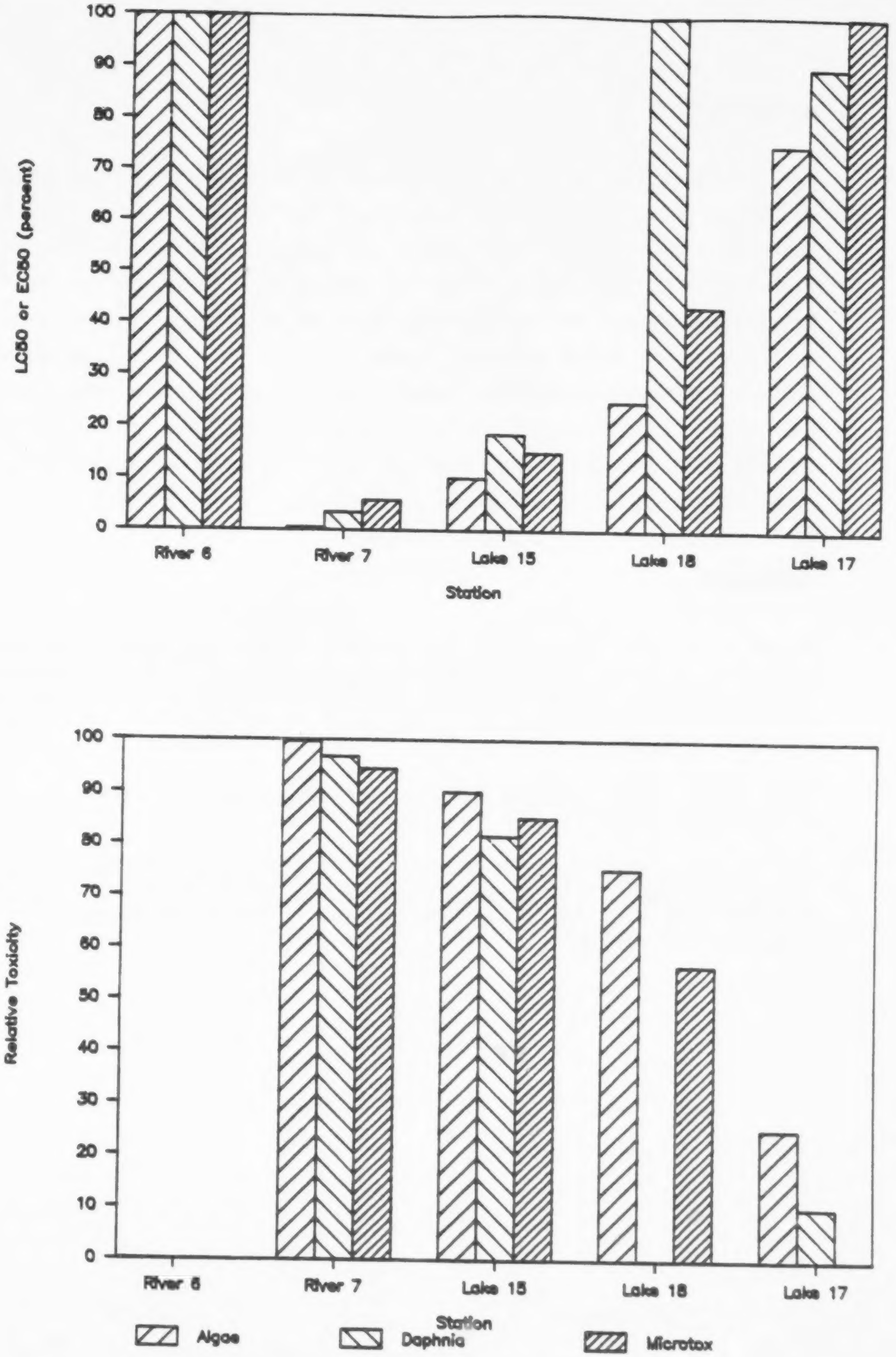


Figure 15-25. Bioassay Responses to Surface Water Samples

Case Discussion

This case study provides an example of a biomonitoring program designed to characterize the relationship between a contaminant source, contaminant concentrations in sediments and water, bioaccumulation in tissues, and receiving-water toxicity. It should be recognized that in most instances, the relationship between contaminant concentrations in the water and toxicity will not be as clear-cut as described in this example. Consideration of the chemical composition in leachate samples, mass balance calculations, and transport and fate mechanisms may indicate that sediments are the primary repository of contaminants. In such instances, sediment bioassays rather than receiving-water bioassays may be better suited for characterization of potential toxic effects on local fauna.

References

Bulich, A.A., M.W. Greene, and D.L. Isenberg. 1981. Reliabilty of the bacterial luminescence assay for determination of the toxicity of pure compounds and complex effluent. pp. 338-347. In: Aquatic toxicology and hazard assessment: Proceedings of the fourth annual symposium. ASTM STP 737. D.R. Branson and K.L. Dickson (eds). American Society for Testing and Materials, Philadelphia, PA.

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CASE STUDY 12: SAMPLING OF SEDIMENTS ASSOCIATED WITH SURFACE RUNOFF

Point Illustrated

- Contaminated sediments associated with surface runoff pathways (rivlets or channels) are indicative of the migration of chemicals via overland flow.

Introduction

This facility is a secondary lead smelting plant which began operation in 1976. The plant reclaims lead from materials such as waste automotive batteries, byproducts of lead weight manufacture, and wastewater sludges. Lead grid plates from salvaged batteries are temporarily stored on site in an open pile prior to being re-melted. It is therefore appropriate to conduct some form of runoff sampling to monitor migration of contaminants from the site via this route.

Facility Description

The facility covers approximately 2,000 ft^2 and is situated in an area primarily used for farming. A creek flows adjacent to the plant and drains into a major river 6 miles west of the site. Population is sparse with the nearest town 4 miles to the south. In the past, there have been four on-site impoundments in operation and two landfills. In addition, blast furnace slag, lead grid plates, and rubber chips from the recycled batteries have been stored in two on-site waste piles.

Sediment Sampling

Four sediment samples (020, 022, 025, and 027) were collected from surface runoff pathways and a creek which receives runoff from the site. Figure 15-26 shows the locations of the runoff pathways in relation to the facility and the four sampling points. Additional sediment samples were collected from the creek at various points upstream and downstream of known overland leachate seeps and surface water runoff routes. The program design enabled comparison between concentrations at different sections of the creek and background locations in relation to the runoff pathways.

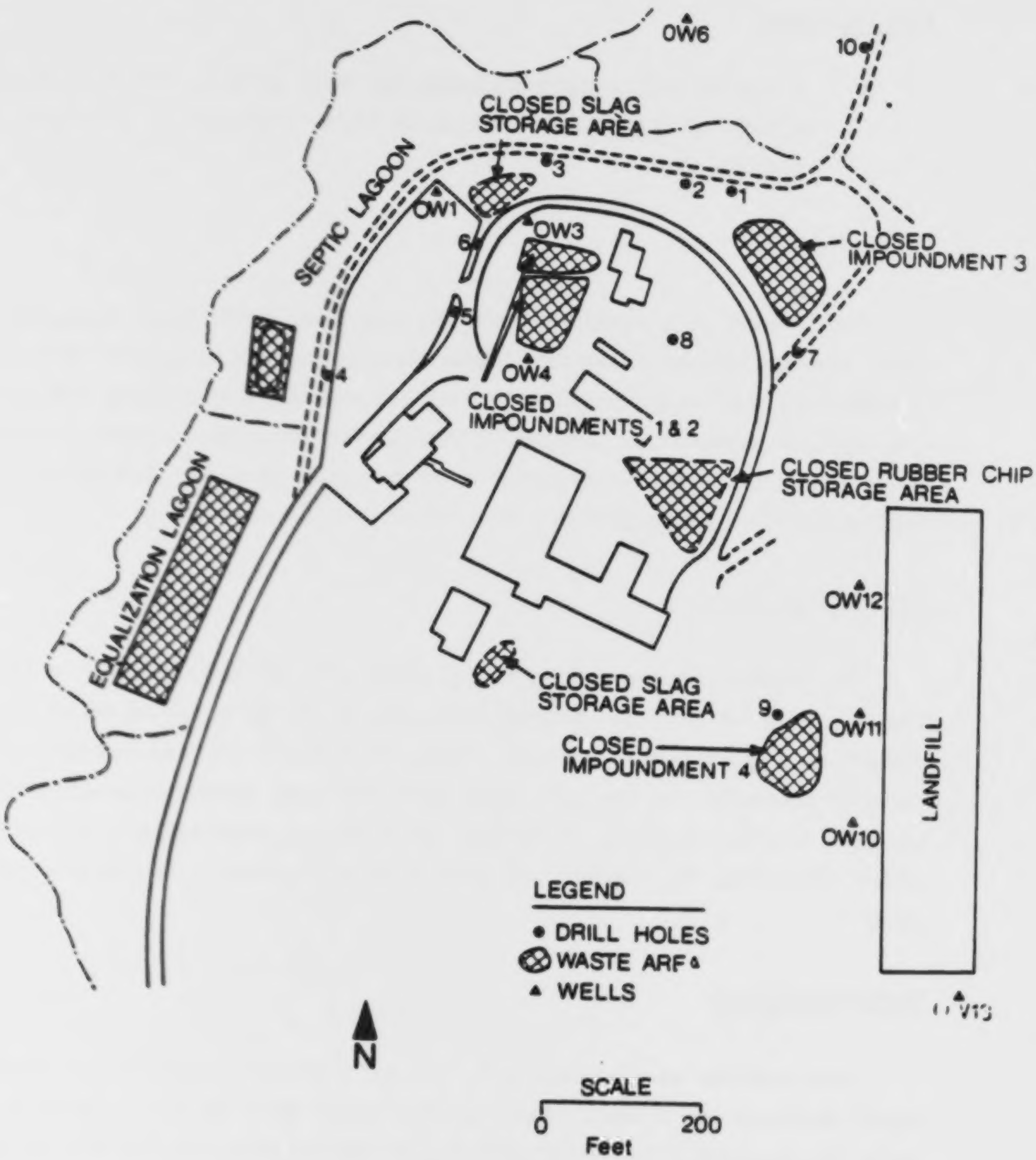

OW6
10
CLOSED SLAG STORAGE AREA
3
2
1
SEPTIC LAGOON
OW1
OW3
6
CLOSED IMPOUNDMENT 3
5
8
7
4
OW4
CLOSED IMPOUNDMENTS 1 & 2
CLOSED RUBBER CHIP STORAGE AREA
EQUALIZATION LAGOON
OW12
CLOSED SLAG STORAGE AREA
9
OW11
CLOSED IMPOUNDMENT 4
LANDFILL
OW10
LEGEND
DRILL HOLES
WASTE AREA
WELLS
OW13
N
SCALE
0
200
Feet

Figure 15-26. Surface Water and Sediment Sample Locations

Results

Table 15-11 presents the concentrations of lead and arsenic measured on the four surface runoff pathways and at location 029, which represents an upstream background concentration (Figure 15-26). It is clear that highly elevated levels of lead were detected in all four of the runoff pathway samples. The highest concentration of lead, 1,900 ppm, was detected in the western most portion of the site. Runoff pathway sediment at the northern end of the facility, adjacent to the slag storage area, recorded 1,600 ppm of lead. Concentrations of this order represent a substantial source of sediment contamination.

Table 15-11

ARSENIC AND LEAD CONCENTRATIONS (PPM) IN RUNOFF SEDIMENT SAMPLES

	Sampling Location				
Contaminant	# 020	# 022	# 025	# 027	Background # 029
Arsenic	11.0	9.6	2.0	8.9	< .1
Lead	1300	1900	1600	1700	11.0

Case Discussion

This case illustrates the importance of monitoring surface runoff pathways, since they can represent a major route of contaminant migration from a site, particularly for contaminants which are likely to be sorbed on or exist as fine particles. This type of monitoring is especially useful for units capable of generating overland flows. Such monitoring can establish the need for corrective measures (e.g., surface runon/runoff controls and/or some form of waste leachate collection system).

CASE STUDY 13: SAMPLING PROGRAM DESIGN FOR CHARACTERIZATION OF A WASATEWATER HOLDING IMPOUNDMENT

Points Illustrated

- Sampling programs must consider three-dimensional variation in contaminant distribution in an impoundment.
- Sampling programs must encompass active areas near inflows and outflows, and potentially stagnant areas in the corner of an impoundment.

Introduction

This study was conducted to assess whether an active liquid waste impoundment could be assumed to be of homogenous composition for the purpose of determining air emissions. This case shows the design of an appropriate sampling grid to establish the three-dimensional composition of the impoundment.

Facility Description

The unit being investigated in this study is a wastewater impoundment at a chemical manufacturing plant. The plant primarily produces nitrated aromatics and aromatic amines. Raw materials include benzene, toluene, nitric acid, and sulphuric acid. Wastewater from the chemical processing is discharged into the impoundment prior to being treated for release into a nearby water body. The impoundment has an approximate surface area of 3,750 m^2 and a depth of 3 m.

Sampling Program

For the most part, sampling involved the collection of grab samples using an extended reach man-lift-vehicle. The program was designed to collect samples at different locations and depths in the impoundment.

Sampling Locations and Procedures--

Sampling Grid - The wastewater impoundment was divided into 15 segments of equal area. Within this grid, eight sampling locations were selected which included all pertinent areas of the impoundment, such as active portions near the inflows and outflows, potential stagnant areas in the corners, and offshore points near the center line of the impoundment.

It was decided to take samples from four depths in the liquid layer and one from the bottom sediments at each of the eight locations. Figure 15-27 shows the impoundment schematic and sampling locations.

Liquid Sampling - A total of 32 liquid grab samples were taken. These were analyzed for the following parameters: for all identifiable volatile organic compounds (VOCs) and semivolatile organic compounds (SVOCs) using gas chromatograph/mass spectroscopy; and selected VOCs and SVOCs by gas chromatography using a flame ionization detector.

Sediment/Sludge Sampling - The bottom layer was sampled using a Ponar grab sampler. The same analyses were performed on the eight sediment/sludge samples as on the liquid samples.

Meteorological Monitoring - The ambient meteorological conditions were monitored throughout the sampling period, including wind speed, wind direction, and air temperature. A video camera was also used to record the movement of surface scum on the impoundment.

Table 15-12 summarizes the sampling locations and analyses, including locations where QC data were collected.

Results

From the sampling program, it was discovered that approximately 99 percent of the organic compounds (by weight) were contained in the bottom sludge layer.

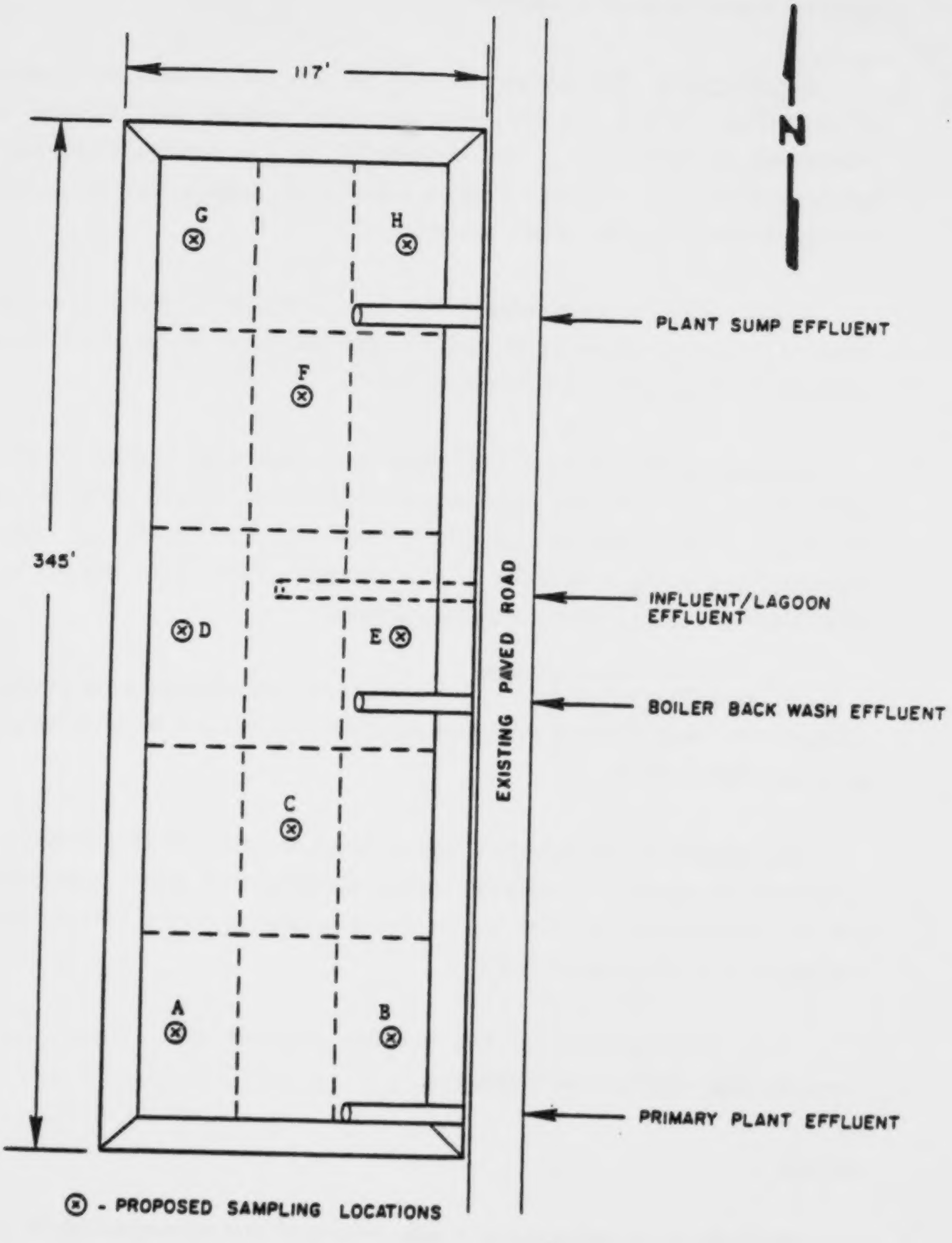

117'
345'
N
G
H
F
D
E
C
A
B
EXISTING PAVED ROAD
PLANT SUMP EFFLUENT
INFLUENT/LAGOON EFFLUENT
BOILER BACK WASH EFFLUENT
PRIMARY PLANT EFFLUENT
⊗ - PROPOSED SAMPLING LOCATIONS

Figure 15-27. Schematic of Wastewater Holding Impoundment Showing Sampling Locations

TABLE 15-12

SUMMARY OF SAMPLING AND ANALYSIS PROGRAM FOR WASTE WATER IMPOUNDMENT

Location	Depth (Feet)	Sample Analyses						
		GC/FID VOA	GC/MS VOA	TOC	POC	Onsite Parameters[a]	GC/FID SVOC	GC/MS SVOC
A-1	0-1	X	X	X	X	X	X	X
A-2	2	X				X	X	
A-3	4	X				X	X	
A-4	6	X				X	X	
A-5	Bottom Sediment	X	X	X		X	X	X
B-1	0-1	X	X	X	X	X	X	X
B-2	2	X				X	X	
B-3	4	X				X	X	
B-4	6	X				X	X	
B-5	Bottom Sediment	X	X	X		X	X	X
C-1	0-1	X	X	X	X	X	X	X
C-2	2	X				X	X	
C-3	4	X				X	X	
C-4	Bottom Sediment	X	X	X		X	X	X
D-1	0-1	X	X	X	X	X	X	X
D-2	2	X				X	X	
D-3	4	X				X	X	
D-4	6	X				X	X	
D-5	Bottom Sediment	X	X	X		X	X	X

a Includes pH, turbidity, specific conductance, and dissolved oxygen measurements.
X Indicates locations where QC samples were collected.

TABLE 15-12
SUMMARY OF SAMPLING AND ANALYSIS PROGRAM FOR WASTE WATER IMPOUNDMENT
PAGE TWO

Location	Depth (Feet)	Sample Analyses						
		GC/FID VOA	GC/MS VOA	TOC	POC	Onsite Parameters[a]	GC/FID SVOC	GC/MS SVOC
E-1	0-1	X	X	X	X	X	X	X
E-2	2	X				X	X	
E-3	4	X				X	X	
E-4	6	X				X	X	
E-5	Bottom Sediment	X	X	X		X	X	X
F-1	0-1	X	X	X	X	X	X	X
F-2	2	X				X	X	
F-3	4	X				X	X	
F-4	6	X				X	X	
F-5	Bottom Sediment	X	X	X		X	X	X
G-1	0-1	X	X	X	X	X	X	X
G-2	2	X				X	X	
G-3	4	X				X	X	
G-4	6	X				X	X	
G-5	Bottom Sediment	X	X	X		X	X	X
H-1	0-1	X	X	X	X	X	X	X
H-2	2	X				X	X	
H-3	4	X				X	X	
H-4	6	X				X	X	
H-5	Bottom Sediment	X	X	X		X	X	X

a Includes pH, turbidity, specific conductance, and dissolved oxygen measurements.
X Indicates locations where QC samples were collected.

Vertical and horizontal variation in the composition of the lagoon was apparent. The degree of horizontal variation was relatively small, but sample point "A" showed consideraby higher concentrations of 2,4-dinitrophenol than the other locations. This could have resulted from a recent discharge from the outflow at the southern end of the impoundment. Vertical variation in composition showed a general trend of increasing concentration with depth, but certain chemicals tended to have higher concentrations at mid-depth in the impoundment.

Case Discussion

This case provides an example of a sampling program at an areal source designed to yield accurate information for characterizing air emissions from the unit. The study illustrated the importance of characterizing the organic composition of the lagoon in three dimensions and considering variations resulting from inflow and outflow areas.

It should be mentioned that this study did not consider variation in the chemical composition of the impoundment with time. To obtain this information, it would be necessary to conduct subsequent sampling programs at different times. From this study, it is apparent that chemical composition varies both horizontally and vertically, and is likely to change depending on inflows and outflows of wastes. This sampling program is therefore limited to effectively characterizing composition at a single point in time.

CASE STUDY 14: USE OF AIR MONITORING DATA AND DISPERSION MODELING TO DETERMINE CONTAMINANT CONCENTRATIONS DOWN-WIND OF A LAND DISPOSAL FACILITY

Point Illustrated

- How to use air dispersion modeling and air monitoring data to estimate contaminant concentrations.

Introduction

Concern over possible vinyl chloride transport into the residential areas adjacent to a land disposal facility prompted initiation of this study. A preliminary survey involving a minimal sampling effort along with the application of an air dispersion model was used to assess potential health hazards prior to conducting a more thorough monitoring program.

Facility Description

The facility is a landfill which has been in operation since 1963. The facility occupies an area of 583 acres, of which 228 acres contain hazardous and municipal waste. The facility and surrounding terrain is hilly with elevations ranging from 600 to 1150 feet above mean sea level. Residential areas are located immediately adjacent to the south and southeast facility boundaries, as shown in Figure 15-28.

The facility previously received waste solutions from the synthesis of polyvinyl chloride which included the vinyl chloride monomer. Gas generated by municipal waste decomposition and chemical waste volatilization are collected at the site with an elaborate piping system and are burned in a smokeless flare. The primary combustible in the gas is methane, with traces of vinyl chloride present along with other compounds.

Program Design/Data Collection

A preliminary survey using a combination of air monitoring and mathematical modeling was used to assess potential vinyl chloride pollution of the residential areas downwind of the facility. An analysis of meteorological data obtained from a

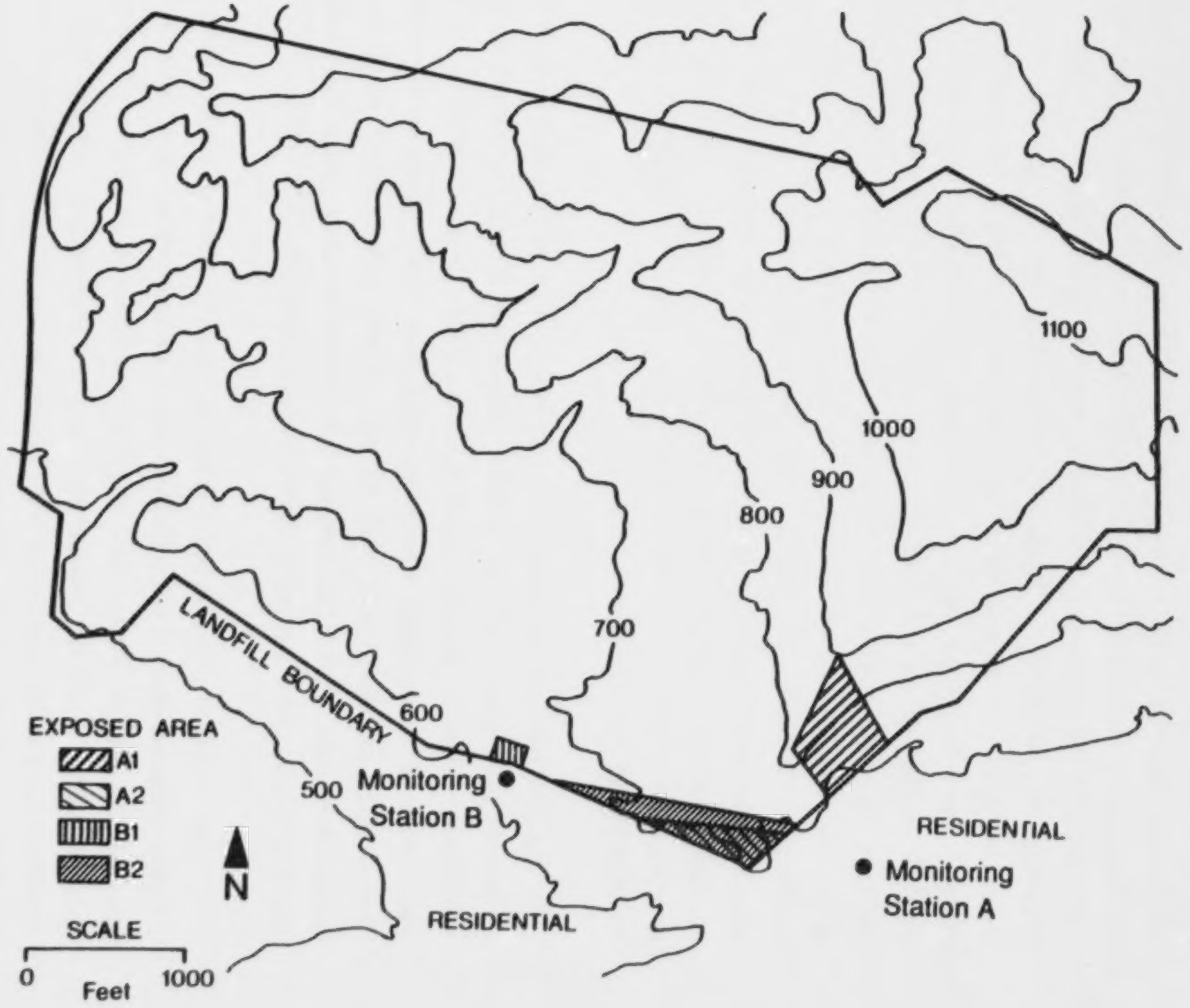

1100
1000
900
800
700
600
500
LANDFILL BOUNDARY
EXPOSED AREA
▨ A1
▨ A2
▥ B1
▨ B2
N
SCALE
0 Feet 1000
Monitoring Station B
RESIDENTIAL
RESIDENTIAL
Monitoring Station A

Figure 15-28. Site Map Showing Location of Air Monitoring Sites A and B

(from Baker and MacKay, 1985)

nearby airport indicated that wind patterns in the area were characterized by a regular daily reversal of wind direction from a daytime westerly sea breeze to a nighttime downslope drainage wind from the north or east beginning after midnight in summer and after sunset in winter. In order to minimize the sampling effort, only two air monitoring stations were selected. The station locations were based on the locations of the nearby receptor areas in conjunction with the prevailing wind conditions and the locations in the landfill where polyvinyl chloride emissions were occurring (Figure 15-28). Station A was located on the upwind side of the residential area 180 meters from the southeast boundary of the facility. This location was selected to measure the plumes from emission area B2 during the daytime westerly winds and from emission area A1 during the nocturnal downslope drainage from the north. Station B was located on the upwind edge of the residential area 25 meters from the southern boundary of the facility. This location was selected to measure the plumes from emission area B1 during nocturnal downslope drainage from the north and from emission area A2 during nocturnal valley drainage from the east. Ambient polyvinyl chloride concentrations upwind of the facility were assumed negligible, so upwind monitoring was not necessary.

Air samples were collected over a 24-hour period on two days in July and on three days in August. The July sampling period was selected to represent typical conditions of light to moderate wind (10 to 15 mph). The August sampling period was conducted to represent worst-case conditions under steady calm winds (less than 8 mph) combined with high air and ground temperatures which tend to maximize emission rates. The samples were collected using Tedlar bags and were analyzed by gas chromatography/flame ionization detection (GC/FID).

Vinyl chloride emission rates from the landfill were estimated using a gas emission equation (Shen, 1981). The estimated emission rates were functions of the area of the landfill where vinyl chloride emissions were known to occur, soil characterisitics, chemical characteristics, and temperature. The emission areas affecting a downwind monitoring station were assumed to vary with different wind directions due to the effects of topographic features. For example, emission area A2 used for nocturnal valley drainage from the east is only a fraction of emission area B2 assumed for the daytime westerly winds, even though both areas represent the same source. These areas were calculated by drawing sectors from each monitoring station along the extremes of wind direction for each wind pattern using ridgelines and the landfill boundary to determine the area limits. A1 and B1 on Figure 15-28 show the exposed areas estimated for valley drainage and sea breeze conditions, respectively.

The estimated emission rates were used in conjunction with an air dispersion model (U.S. EPA, 1981) to predict the concentrations of vinyl chloride at monitoring station A and B. The major input parameters included the gas emission rates discussed above, the source areas, and wind speed. The meteorological and landfill data used in the model predictions corresponded to the air monitoring periods during July and August. The model results were averaged for each of the 24-hour monitoring periods to facilitate comparison with the monitoring data.

Results

Table 15-13 compares the predicted and measured 24-hour average vinyl chloride concentrations at stations A and B for each of the five sampling days. The model results are accurate to within a factor of two for all sampling periods at both stations. The use of on-site meteorological data would probably have improved the accuracy of the predictions since off-site data from the nearby airport may not have reflected localized conditions (e.g., topographic effects) which could effect the wind speed, direction, and air temperature used in the calculations.

Another area where error may have been introduced was in the calculation of emission rates. Several factors could have reduced the accuracy of these estimates including difficulty in calculating the effective emission areas due to the irregular topography, as well as spatial variations in parameters such as soil porosity and depth of landfill cover which were assumed constant in the analysis.

TABLE 15-13

COMPARISON OF MEASURED AND PREDICTED VINYL CHLORIDE CONCENTRATIONS (PPB) (FROM BAKER AND MACKAY, 1985)

Site	Date	March 7-8	March 8-9	August 5-6	August 6-7	August 7-8	5-Day Average
A	Measured	12	5	7	12	9	9
	Model 1	25.1	19.4	40.0	45.7	45.5	35.1
	Model 2	9.1	7.3	14.8	16.7	16.9	13.0
	Model 3	4.9	4.0	8.0	9.0	9.1	7.0
	Model 4	45.9	42.8	76.7	81.1	87.3	66.8
B	Measured	5	7	2	4	<2	4
	Model 1	24.3	13.1	30.4	32.4	32.2	26.5
	Model 2	11.5	6.1	14.2	15.3	15.2	12.5
	Model 3	5.5	3.7	8.4	8.7	8.9	7.0
	Model 4	35.5	28.6	62.8	62.0	66.7	51.1

*Key
Model 1 = ground level point source (Shen, 1982)
Model 2 = virtual point source (Turner, 1969)
Model 3 = virtual point source (U.S. EPA, 1981)
Model 4 = simple box (Gifford and Hanna, 1970)

Case Discussion

Air dispersion models can be useful for estimating concentrations downwind of waste disposal areas. Although many models are available, the ISC (Industrial Source Complex) model (EPA, 1977, 1986) is recommended for most applications. However, other EPA-approved models (e.g., UNAMAP series) can also be used where appropriate. For this preliminary survey, a simpler screening model was used.

Air monitoring should always be performed in conjunction with dispersion modeling to verify the accuracy of model predictions. After the model has been verified, it can be used to estimate downwind concentrations under a wide range of meteorological conditions, under different (e.g., future) waste management scenarios, and at different potential receptor areas (e.g., future residential developments). It can also be used to estimate pollutant concentrations in areas where direct monitoring would be difficult due to limitations in analytical techniques (i.e., concentrations below detection limits), for example, areas where low concentrations of a highly toxic compound are present. Dispersion models are also useful for analyzing multiple sources whose plumes overlap since the incremental contamination associated with each source can be separated. In addition, they are useful for selecting station locations in air monitoring programs since they can estimate the trajectory and extent of the contaminant plume prior to making any measurements.

References

Baker, L.W. and K.P. MacKay. 1985. Screening Models for Estimating Toxic Air Pollution Near a Hazardous Waste Landfill. Journal of Air Pollution Control Association, 35:11.

Shen, T. 1981. Control Techniques for Gas Emissions from Hazardous Waste Landfills. Journal of Air Pollution Control Association, 31:132.

U.S. EPA. 1977. Guidelines for Air Quality Maintenance Planning and Analysis. Vol. 10 (Revised). Procedures for Evaluating Air Quality Impact of New Stationary Sources. EPA-450/4-77-001. Washington, D.C.

U.S. EPA. 1981. *Evaluation Guidelines for Toxic Air Emissions from Land Disposal Facilities*. U.S. EPA, Office of Solid Waste, Washington, D.C.

U.S. EPA. 1986. *Guidelines on Air Quality Models (Revised)*. EPA-450/2-78-027R. Washington, D.C.

CASE STUDY 15: USE OF METEOROLOGICAL DATA TO DESIGN AN AIR MONITORING NETWORK

Points Illustrated

- How to design an air monitoring program
- How to conduct an upwind/downwind monitoring program when multiple sources are involved.

Introduction

An air monitoring program was conducted to characterize hazardous constituents that were being released from a wood treatment facility. Meteorological data were first collected to determine the wind patterns in the area. The wind direction data together with the locations of the potential emission sources were then used to select air sampling locations.

Facility Description

The site is a 12-acre wood treatment facility located in an inland, topographically flat area of the southeast. Creosote and pentachlorophenol are used as wood preservatives, and heavy metal salts have been used in the past. Creosote and pentachlorophenol are currently disposed in an aerated surface impoundment. Past waste disposal practices included treatment and disposal of the metal salts in a surface impoundment, and disposal of contaminated wood shavings in waste piles. The constituents of concern in the facility's waste stream include phenols, cresols, and polycyclic aromatic hydrocarbons (PAH) in the creosote; dibenzodioxins and dibenzofurans as contaminants in pentchlorophenol; and particulate heave metals. The potential emission sources (Figure 15-29) include the container storage facility for creosote and pentachlorophenol, the wood treatment and product storage areas, the aerated surface impoundment for the creosote and pentachlorophenol wastes, and the contaminated soil area which previously contained both the surface impoundment for treating the metal salts and the wood shavings storage area. Seepage from these waste management units has resulted in documented ground water and surface water contamination.

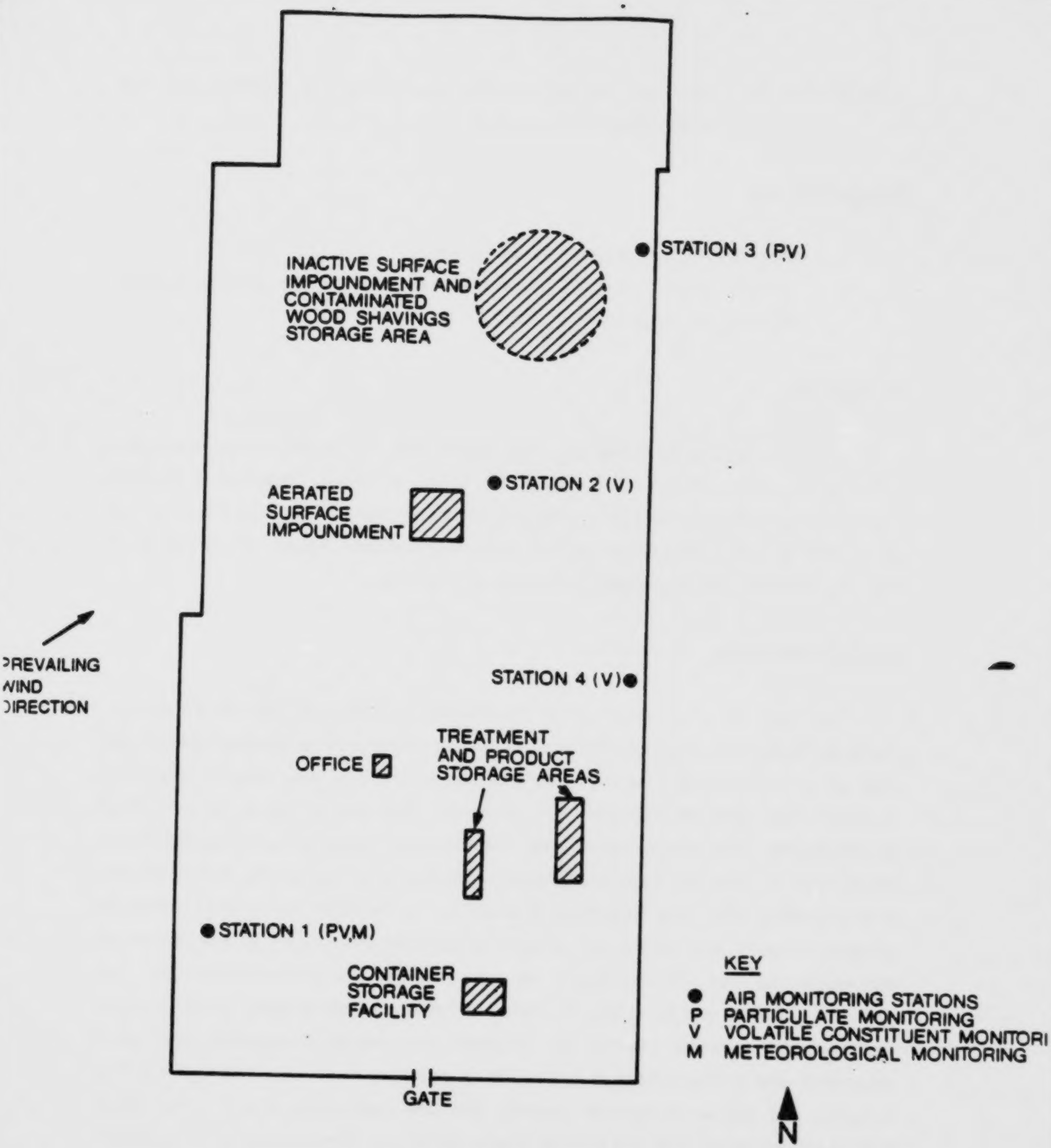

INACTIVE SURFACE IMPOUNDMENT AND CONTAMINATED WOOD SHAVINGS STORAGE AREA
STATION 3 (P,V)
AERATED SURFACE IMPOUNDMENT
STATION 2 (V)
REVAILING
IND
IRECTION
STATION 4 (V)
OFFICE
TREATMENT AND PRODUCT STORAGE AREAS
STATION 1 (P,V,M)
CONTAINER STORAGE FACILITY
GATE
KEY
● AIR MONITORING STATIONS
P PARTICULATE MONITORING
V VOLATILE CONSTITUENT MONITORI
M METEOROLOGICAL MONITORING
N

Figure 15-29. Site Plan and Locations of Air Monitoring Stations

The area surrounding the facility has experienced substantial development over the years. A shopping center is now adjacent to the eastern site perimeter. This development has significantly increased the number of potential receptors for air releases of hazardous constituents.

Program Design/Data Collection

Preliminary Screening Survey—

A limited-on-site air screening survey was first conducted to document air releases of potentially hazardous consituents and to verify the need to conduct an air monitoring program. Total hydrocarbon (THC) levels were measured with a portable THC analyzer downwind of the aerated surface impoundment, wood treatment area, and product storage area. Measurements were also made upwind of all units to provide background concentrations. Because THC levels detected downwind were significantly higher than background levels, a comprehensive air monitoring program was designed and implemented.

Waste Characterization—

To develop an adequate air monitoring program, the composition of wastes handled in each waste management unit was first determined to identify which constituents were likely to be present in the air releases. Existing water quality data indicated contamination of ground water with cresols, phenol, and PAHs and of surface water with phenols, benzene, chlorobenzene, and ethylbenzene. A field sampling program was developed to characterize further the facility's waste stream. Waste water samples were collected from the aerated surface impoundment and soil samples were collected from the heavy metal salt waste treatment/disposal area. Analytical data from this sampling effort confirmed the presence of the constituents previously identified. Additional constituents detected included toluene and xylenes in surface impoundment wastes, and arsenic, copper, chromium, and zinc in the treatment/disposal area.

Based on their individual emission potentials and potentials for health and environmental hazards, the following constituents were selected for measurement in the air monitoring program:

Volatile/semi-volatile constituents: toluene, benzene, total phenols, pentachlorophenol, PAHs, cresols

Particulate constituents: aresenic, copper, chromium, zinc.

Meteorological Data Collection--

Meteorological information is critical for designing an air monitoring program since stations must be located both upwind and downwind of the contaminant sources. Therefore, a one-month meteorological monitoring survey was conducted. The survey was conducted under conditions considered to be representative of the summer months during which air samples would be collected. Summer represented worst-case conditions of light steady winds and warm temperatures. The collected meteorological data showed that the local wind direction was from the southeast. No well-defined secondary wind flows were identified. Minor changes were observed in prevailing wind direction over a 24-hour period due to reduction of wind speed at night.

Initial Monitoring--

The meteorological data were used with the EPA atmospheric dispersion model, ISC (Industrial Source Complex Model), to estimate worst-case air emission concentrations and to help determine the locations for the air sampling stations. The ISC model was used because it is capable of simulating conditions of point and non-point source air emissions. Using the established southeast wind direction, maximum downwind concentrations were predicted for different meteorological conditions (e.g., wind speed). Upwind background stations and downwind monitoring stations were selected based on the predicted dispersion pathways. Since the plumes from the individual waste management areas overlapped, the model also provided a means for separating the incremental contamination due to each source.

Figure 15-29 shows the locations of the selected sampling stations. Station 1 is the upwind background station. Here background volatile concentrations, particulate concentrations, and meteorological conditions were monitored. Stations 2 and 4 were located to identify volatile emissions from the aerated surface impoundment and wood treatment/product storage areas, respectively. Station 3 was located downwind of the inactive surface impoundment/wood shavings disposal area. The location of this station was sited to document releases from these waste management units and to document worst case concentrations of volatiles and particulates at the site perimeter. A trailer-mounted air monitoring station was used to supplement the permanent stations and to account for any variability in wind direction.

Sample Collection--

The air quality monitoring was conducted over a three-month period during the summer. Meteorological variables were measured continuously on site throughout the study. Air samples were taken over a 24-hour period approximately every six days. The sampling dates were flexible to insure that worst-case conditions were documented.

Volatile and semi-volatile constituents were sampled by drawing ambient air through a sampling cartridge containing sorbent media. A modified high volume sampler consisting of a glass fiber filter with a polyurethane foam backup sorbent (EPA Method TO4) was used to sample for total phenols, pentachlorophenol, and PAHs. Benzene and toluene were collected on Tenax sampling cartridges (EPA Method TO1) and cresol was collected on silica gel cartridges (NIOSH Method Z001). Particulates were collected on filter cassettes using high-volume samplers.

In addition to the analytical parameters previously discussed, Appendix VIII constituents and RCRA metals were analyzed on the first few sets of samples. These analyses were conducted to identify air releases of constituents other than those known to be present. The results indicated that no additional constituents were present in significant concentrations, so the additional analyses were dropped for the remainder of the study.

Program Results/Data Analysis

Standard sampling/analytical methods were available for all of the target monitoring constitutents. Analytical detection limits were below specific health and environmental criteria for all constituents except cresol. The high analytical detection limit for cresol which exceeded reference health criteria complicated data analysis. This difficulty was handled by the routine collection and analysis of waste water samples during the air monitoring program. These data were used to estimate cresol levels in the air by comparing its emission potential index to the other air monitoring constituents which have relatively low detection levels.

Analytical results obtained during this sampling program established that fugitive air emissions exceeded reference health criteria. Source control measures were implemented to reduce emission concentrations below health criteria levels. Subsequent air monitoring was conducted at the same stations used previously on a weekly basis immediately after implementation of the remedial measures, and on a quarterly basis thereafter.

Case Discussion

This case illustrates the sequence of tasks needed to design an air monitoring program at a site with multiple air emission sources. An initial problem at this site was the lack of evidence that air emissions posed a threat to public health or the environment. An initial field survey was conducted to identify local prevailing wind patterns and to identify potential downwind receptors of fugitive air emissions.

The meteorological survey results were used to design an effective monitoring network. Monitoring station locations were selected to obtain background conditions and to document air releases downwind of each emission source. Also, the monitoring strategy included use of a portable sampling station to provide flexibility in sampling locations to account for variation in wind direction. Spatial variability in air concentration levels was assesed with the aid of an air dispersion model to assist in data interpretation.

Air emissions data documented an air release of hazardous constituents above health crtiteria levels. Remedial measures were implemented, and periodic subsequent monitoring was conducted to insure compliance with health criteria.

References

Methods T01 and T04, Compendium of Methods for Determination of Toxic Organic Compounds in Ambient Air, 1984, EPA-600/4-84-041.

Method Z001, NISOH Manual of Analytical Methods, 1984, National Institute of Occupational Safety and Health.

CASE STUDY 16: USE OF THE 40 CFR 261 LISTING BACKGROUND DOCUMENTS FOR SELECTING MONITORING CONSTITUENTS

Point Illustrated

- The 40 CFR 261 Listing Background Documents can be of direct help in selecting monitoring constituents.

Introduction

The RCRA Hazardous Waste Listing Background Documents developed for the identification and listing of hazardous wastes under 40 CFR Part 261 represent one source of potential information on waste-specific constituents and their physical and chemical characteristics. The documents contain information on the generation, composition, and management of listed waste streams from generic and industry-specific sources. In addition to identifying hazardous constituents that are present in the wastes, the documents may also provide data on potential decomposition products. In some background documents, migratory potentials are discussed and exposure pathways are identified.

Appendix B of the Listing Document provides more detailed information on the fate and transport of hazardous constituents. Major physical and chemical properties of selected constituents are listed, including molecular weights, vapor pressures and solubilities, octanol-water partition coefficients, hydrolysis rates, biodegradation rates, and volatilization rates. Another section of the appendix estimates the migratory potential and environmental persistence of selected constituents based on a conceptual model of disposal in an unconfined landfill or lagoon.

The appropriate uses and limitations of the Listing Documents are outlined in Table 15-14. A case study on how the Documents may be used in investigating a release follows.

TABLE 15-14

USES AND LIMITATIONS OF THE LISTING BACKGROUND DOCUMENTS

Uses	Limitations
● Identifies the hazardous constituents for which a waste was listed	● Applicable only for listed hazardous wastes
● In some cases, provides information on additional hazardous constituents which may be present in a listed waste	● Industry coverage may be limited in scope, e.g., the wood preserving industry. Listing Documents only cover organic preservatives, not inorganics (-15 percent of the industry), such as inorganic arsenic salts
● In some cases, identifies decomposition products of hazardous constituents	● Data may not be comprehensive, i.e., not all potentially hazardous constituents may be identified. Generally, limited to the most toxic constituents comon to the industry as a whole
● Provides overview of industry; gives perspective on range of waste generated (both quantity and general characteristics)	● Data may not be specific. Constituents and waste characteristic data often represent an industry average which encompases many different types of production processes and waste treatment operations
● May provide waste-specific characteristics data such as density, pH, and leachability	● Listing Documents were developed from data/reports available to EPA at the time, resulting in varying levels of detail for different documents
● May provide useful information on the migratory potential, mobility, and environmental persistence of certain hazardous consistuents	● Hazardous waste listings are periodically updated and revised, yet this may not be reflected in the Background Documents
● May list physical and chemical properties of selected constituents	● Listing Documents for certain industries, e.g., the pesticides industry, may be subject to CBI censorship due to the presence of confidential business information. In such cases, constituent data may be unavailable (i.e., expurgated from the document)

Facility Description

The facility is a wood preserving plant located in the southeast. The facility uses a steaming process to treat southern pine and timber. Contaminated vapors from the wood treating process are condensed and transported to an oil/water separator to reclaim free oils and preserving chemicals. The bottom sediment sludge from this and subsequent waste water treatment units is a RCRA listed hazardous waste: K001.

Use of Listing Background Documents

Due to the presence of small, but detectable, levels of phenolic compounds in the ground water of an adjacent property, a RCRA Facility Assessment (RFA) was conducted and it was determined that a release from the facility had occurred. The owner was instructed to conduct a RCRA Facility Investigation (RFI). Before embarking on an extensive waste sampling and analysis program, the owner decided to explore existing sources of information in order to better focus analytical efforts.

The owner obtained a copy of the Wood Preserving Industry Listing Background Document from the RCRA Docket at EPA Headquarters. He also had available a copy of 40 CFR Part 261, Appendix VII, which identifies the hazardous constituents for which his waste was listed. For K001, he found the following hazardous constituents listed: pentachlorophenol, phenol, 2-chlorophenol, p-chloro-m-cresol, 2,4-dimethylphenyl, 2,4-dinitrophenol, trichlorophenols, tetrachlorophenols, 2,4-dichlorophenol, creosote, chrysene, naphthalene, fluoranthene, benz(b)fluoranthene, benz(a)pyrene, ideno(1,2,3-cd)pyrene, benz(a)anthracene, dibenz(a)anthracene, and acenaphthalene.

From the Summary of Basis for Listing section in the Listing Document, the owner found that phenolic compounds are associated with waste generated from the use of pentachlorophenol-based wood preservatives, and that polynuclear aromatic hydrocarbons (PAHs), i.e., chrysene through acenaphthalene in Appendix VII, are associated with wastes from the use of creosote-based preservatives.

Examining the facility records, he determined that pentachlorophenol had been the sole preservative used; moreover, it had come from a single manufacturer. Based on a demonstrable absence of creosote use, the owner felt confident in excluding creosote and PAHs.

To help focus on which phenolics might be present in his waste, the owner turned to the Composition section of the Listing Document. In Table 4, he found typical compositions of commercial grade pentachlorophenol. The sample from his manufacturer contained 84.6 percent pentachlorophenol, 3 percent tetrachlorophenol, and ppm levels of polychlorinated dibenzo-p-dioxins and dibenzo-furans. The owner was surprised by the absence of the other phenolics mentioned in Appnedix VII, and he was concerned by the presence of dioxins and furans. Reading the text carefully, he discovered that the majority of the phenolic compounds listed as hazardous constituents of the waste are actually decomposition products of penta- and tetrachlorophenol. He also learned that while the Agency had ruled out the presence of tetrachlorodibenzo(p)dioxin (TCDD) in the listed waste (except where incinerated), they had not ruled out the possibility that other chlorinated dioxins might be present: "... chlorinated dioxins have been found in commercial pentachlorophenol and could therefore be expected to be present in very small amounts in some wastes." Due to their extreme toxicity and because his facility had historically used the commercial pentachlorophenol with the highest concentration of dioxins and furans, the owner thought it prudent to include a scan for dioxins in his waste analysis plan.

The owner found no further data in the Composition section to help him narrow the list of phenolics; however, Table 6 gave a breakdown of organic compounds found in different wood preserving plants (i.e., steam process vs. Boneton conditioning), but only two phenolics were listed. A note in the text highlights one of the limitations of using the Listing Document: "The absence in this table (Table 6) of certain components ... probably indicates that an analysis for their presence was not performed rather than an actual absence of the component." It should be kept in mind that the waste analyses in the Listing Background Documents are not comprehensive and that they are based, as the Agency acknowledges, on data available at the time. In the absence of more detailed waste-specific data, the owner decided to include pentachlorophenol, tetrachlorophenol, unsubstituted phenol, and the six listed decomposition-product phenolic compounds in his waste analysis plan.

In reading the Listing Documents, the owner found useful information for other phses of the RFI. In the Migratory Potential Exposure Pathways section, he learned that pentachlorophenol is highly bioaccumulative, with an octanol/water partition coefficient of 102,000. Tetrachlorophenol, tri-chlorophenol, and dichlorophenol are likewise bioaccumulative, with octanol/water coefficients of 12,589, 4,169, and 1,380, respectively. He also learned that the biodegradability of pentachlorophenol is concentration limited.

In Appendix B of the Listing Background Documents; Fate and Transport of Hazardous Consituents, the owner found data sheets for six out of nine phenolic compounds, also some for dioxins and furans. Information on water chemistry, soil attentuation, environmental persistence, and bioaccumulation potential were listed along with chemical and physical properties such as solubility and density.

Case Discussion

Although the Listing Background Document did not provide the owner with enough specific data to fully characterize his waste, it did help him refine the list of monitoring constituents, alert him to the potential presence of dioxins, and gave him physical and chemical waste characteristic data which could be useful in predicting contaminant mobility.

CASE STUDY 17: SELECTION AND EVALUATION OF A SOIL SAMPLING SCHEME

Points Illustrated

- Sampling methodologies must be properly selected to most appropriately characterize soil contamination.

- Statistical analyses can be used to evaluated the effectiveness of a chosen sampling scheme.

Introduction

Selection of a sampling scheme appropriate for a soil contamination problem is dependent on the objectives of the sampling program. A grab sampling scheme may be employed, however, grab sampling can produce a biased representation of contaminant concentrations because areas of gross contamination are most often chosen for sampling. Random sampling can provide an estimate of average contaminant concentrations across a site, but does not take into account differences due to the proximity to waste sources and soil or subsurface heteorogeneities. A stratified random sampling scheme allows these factors to be considered and, thus, can be appropriate for sampling. Depending on the site, additional sampling using a grid system may be needed to further define the areas of contamination.

Facility Description

The example facility operated as a secondary lead smelter from World War II until 1984. Principal operations at the smelter involved recovery of lead from scrap batteries. Air emissions were not controlled until 1968, resulting in gross contamination of local soils by lead particulates.

Land use around the smelter is primarily residential mixed with commercial/industrial. A major housing development is located to the northeast and a 400-acre complex of single family homes is located to the northwest. Elevated blood lead levels have been documented in children living in the area.

Program Design/Data Collection

Initial soil sampling was conducted at the lead smelter and in the surrounding area to document suspected contamination. Sample locations were selected based on suspected areas of deposition of airborne lead and in areas where waste dumping was known to have occurred. High lead concentrations were documented in samples collected from these sources. Because data obtained in the exploratory sampling program (grab sampling) were not adequate to delineate the areal extent of contamination, a stratified random sampling scheme was developed.

Based on wind rose data and the behavior of airborne particulate matter, a sampling area was selected encompassing a 2 mile radius from the smelter. Specific sampling sites were selected using a stratified random sampling scheme. The study area was divided into sectors each 22.5 degrees wide and aligned so that prevailing winds bisected the sectors. Each sector was further divided into approximately one-tenth mile sections. A random number generator was used to select first the direction and then the section. Random numbers generated were subject to the following restrictions: two-thirds of the sites selected had to fall in the major downwind direction; both residential and non-residential sites had to exist in the sector; sampling sections were eligible for repeat selection only if they were geographically within 1/2 mile from the smelter or if the section contained both residential and non-residential sites. Sites that were biased towards lead contamination from other than the lead smelter were not sampled (e.g., gas stations and next to roads). A total of 20 soil sampling locations were selected, 10 at residences and 10 at non-residential sites such as schools, parks, playgrounds and daycare centers.

Sample cores were collected using a 3/4 inch inner diameter stainles steel corer. Total sample depth was 3 inches. A minimum of four and maximum of six samples were collected at each sampling location within a 2 ft. radius. Cores were divided into 1 inch increments and the corresponding increments were composited from each depth to make up one sample. This approach provided data on lead stratification in the top 3 inches of soil. All samples were analyzed for total lead.

The results of the stratified random sampling indicated several acres with over 2,000 ppm lead in the soil. To further define the extent of these areas, a grid sampling plan was designed. Seven humdred and fifty foot increments were used. The grid was oriented along the axis of the plume. Both residential and non-residential areas were sampled. At each grid point, four 3 inch cores were collected 30 m from the grid point in each major compass direction. The cores were composited by depth as discussed above.

Program Results/Data Anaysis

Analytical results from the soil sampling program indicated significant lead contamination within the study area. Maximum concentrations observed were 2,000 ppm lead with a background level of 300 ppm. Krieging of the data from the grid sampling plan was used to develop a contour map as shown in Figure 15-30. Lead concentrations were highest northwest and southwest of the smelter.

Case Discussion

Because of the large area potentially affected by lead emissions, development of a sequential sampling plan was necessary to determine the maximum soil lead concentrations surrounding the smelter and the areas having elevated concentrations. A grab sampling scheme was first used to confirm that soil contamination existed. A stratified random sampling scheme was developed to provide representative data throughout the study area. This type of sampling allowed consideration of prevailing wind directions and the need to sample both residential and non-residential areas. To further define areas of contamination, a grid sampling plan was developed. From these data, contour maps were prepared delineating areas with elevated concentrations.

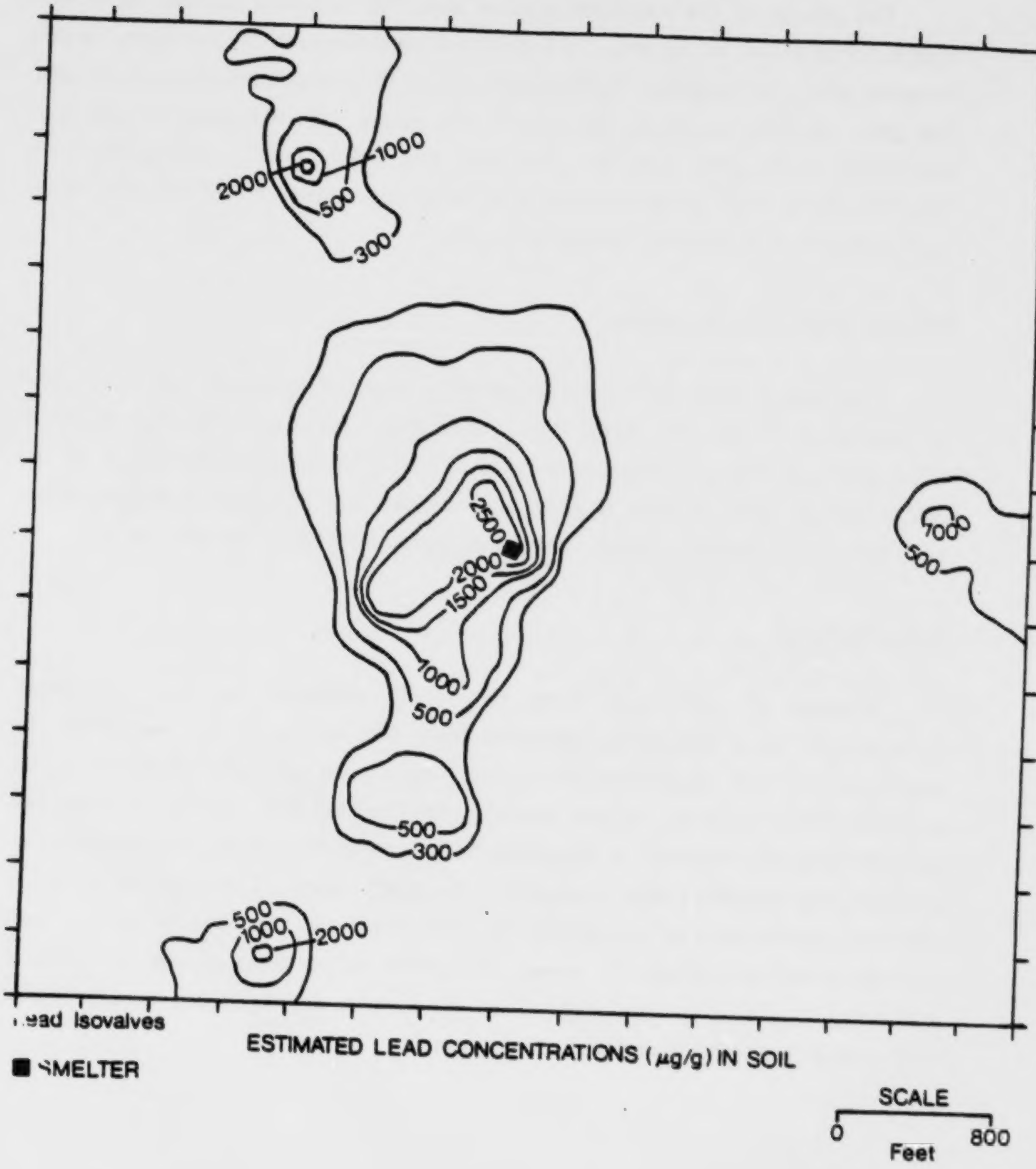

2000
1000
500
300
2500
2000
1500
1000
500
500
300
700
500
500
1000
2000
Lead Isovalves
■ SMELTER
ESTIMATED LEAD CONCENTRATIONS (μg/g) IN SOIL
SCALE
0
800
Feet

Figure 15-30. Contour Map of the Lead Concentrations in ppm Around the Smelter

CASE STUDY 18: SAMPLING OF LEACHATE FROM A DRUM DISPOSAL AREA WHEN EXCAVATION AND SAMPLING OF DRUMS IS NOT PRACTICAL

Points Illustrated

- It is not always possible to perform waste characterization prior to establishing the RFI monitoring scheme since the waste may not be directly accessible, as in the case of buried drums.

- When direct waste characterization is not practical, release monitoring should be performed for the constituents listed in Appendix B of Volume I of the RFI Guidance.

Introduction

Insufficient waste characterization data existed for a former drum disposal facility that was suspected of releasing contaminants into the subsurface environment. Leachate within the disposal pit was sampled and analyzed for all constituents listed in Appendix B of Volume I of the RFI Guidance. The resulting information was used to determine the major waste constituents to be monitored during the RFI.

Facility Description

The unit of concern was a pit containing an estimated 15,000 drums. Due to poor record keeping by the facility operator, adequate information regarding the contents of the drums was not available. It was also not known if the drums were leaking and releasing contaminants to the environment. Since insufficient data existed regarding the drum contents, it was not known what constituents should be monitored in nearby ground and surface waters. Due to the risk to workers and the potential for causing a multi-media environmental release, excavation and sampling of the drums to determine their contents was not considered practical. Instead, it was decided that leachate around the perimeter of the drum disposal pit would be sampled to identify constituents which may be of concern.

Program Design/Data Collection

In order to determine the physical extent of the buried drums a geophysical survey was conducted using a magnetometer. Borings were located at positions having lower magnetometer readings than surrounding areas in order to minimize the potential for drilling into drums.

Soil borings were performed around the perimeter of the drum disposal pit, as defined by the magnetometer survey. Drilling was accomplished using a hydraulic rotary drill rig with a continuous cavity pump. Water was used as the drilling fluid. In order to prevent surface runoff from entering and to control gaseous releases from the borehole, primary and secondary surface collars were installed. These consisted of 5-foot sections of 4-inch steel pipe set in concrete. A device to control liquid and gaseous releases from the borehole was threaded onto the collars to form a closed system (Figure 15-31).

Drilling was performed using a wireline operated tri-cone roller bit with a diamond tipped casing advancer (Figure 15-32). Water was pumped down inside the casing and out the drill bit, returning up the borehole or entering the formation. The use of water to aid in drilling also helped reduce the escape of gases from the borehole. Air monitoring showed no releases. Split-spoon samples were collected at 5-foot intervals during the drilling and a leachate monitoring well was installed at each boring location.

The soil and leachate samples were analyzed for the compounds contained in Appendix B of Volume I of the RFI Guidance.

Program Results/Data Analysis

The leachate samples were found to contain high levels of volatile organic compounds including 2-butanone, 4-methyl-2-pentanone, and toluene. Concentrations were higher on the downgradient side of the pit.

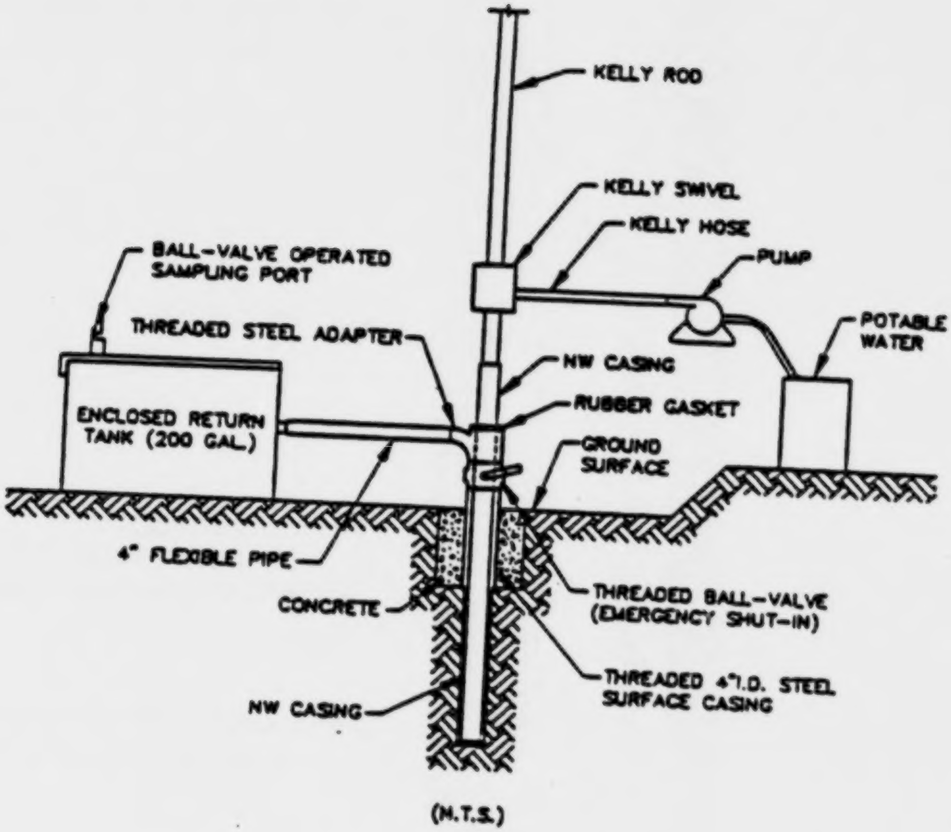

KELLY ROD
KELLY SWIVEL
KELLY HOSE
PUMP
BALL-VALVE OPERATED SAMPLING PORT
THREADED STEEL ADAPTER
POTABLE WATER
NW CASING
RUBBER GASKET
ENCLOSED RETURN TANK (200 GAL.)
GROUND SURFACE
4" FLEXIBLE PIPE
THREADED BALL-VALVE (EMERGENCY SHUT-IN)
CONCRETE
THREADED 4"I.D. STEEL SURFACE CASING
NW CASING
(N.T.S.)

Figure 15-31. Schematic Diagram of Gas Control System Utilized at Pit

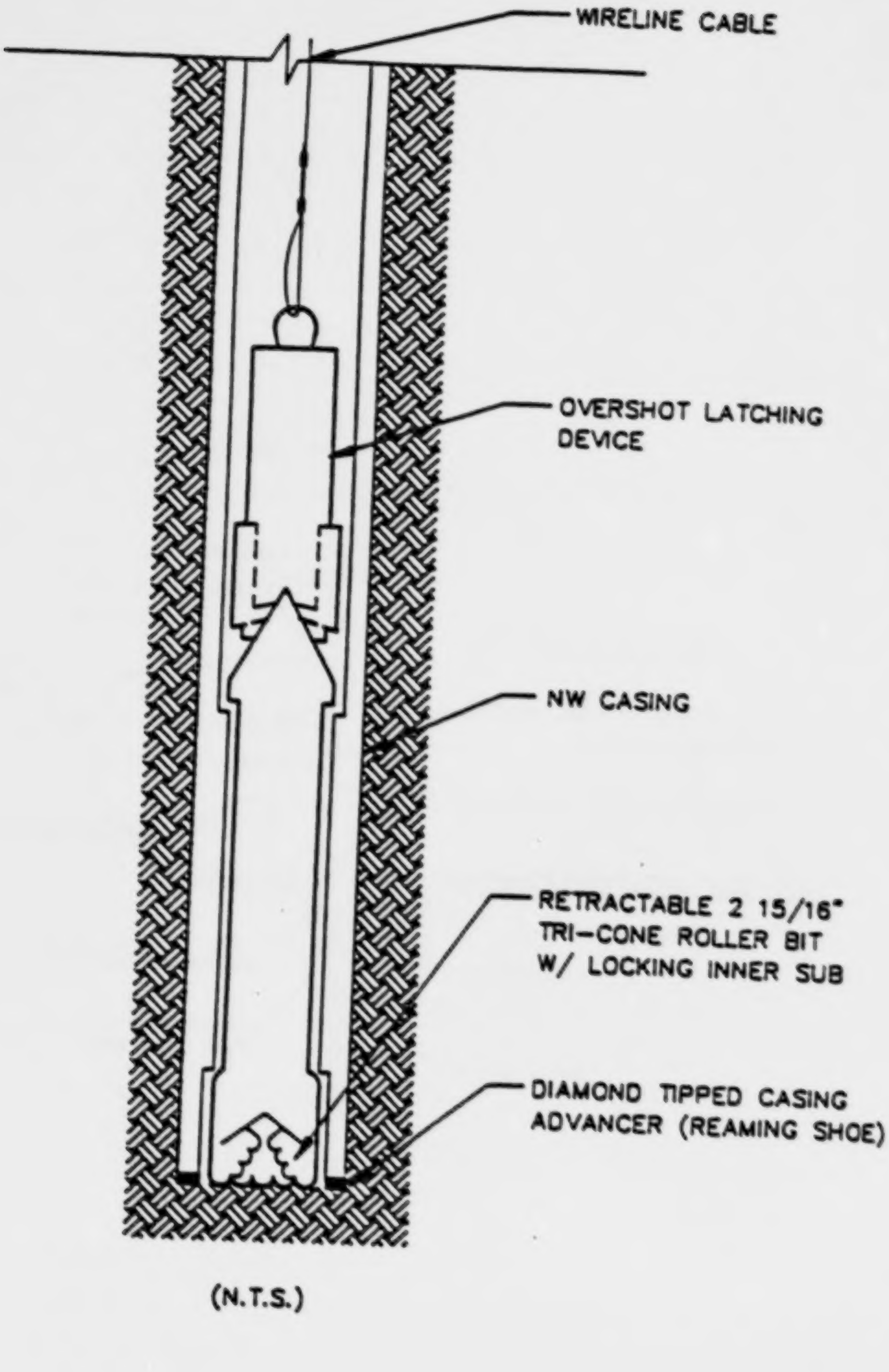

WIRELINE CABLE
OVERSHOT LATCHING DEVICE
NW CASING
RETRACTABLE 2 15/16" TRI-CONE ROLLER BIT W/ LOCKING INNER SUB
DIAMOND TIPPED CASING ADVANCER (REAMING SHOE)
(N.T.S.)

Figure 15-32. Schematic Drawing of Wireline Drill Bit and Reaming Shoe

Case Discussion

Leachate sampling can be useful in determining whether buried drums are leaking and in identifying the materials that are being released. This methodology can be safer and more cost effective than excavation and sampling of individual drums. It also identifies the more soil-mobile constituents of the leachate.

The data gathered in this case study were used in designing a monitoring program, and the contaminants found were used as indicator compounds to link downgradient ground water contamination to this waste disposal unit.

CASE STUDY 19: CORRELATION OF CONTAMINANT RELEASES WITH A SPECIFIC WASTE MANAGEMENT UNIT USING GROUND WATER DATA

Point Illustrated

- Development of an effective ground water monitoring program can tie releases of contaminants to specific waste mangement units.

Introduction

Documentation of a release from a specific waste management unit may require the development of a comprehensive ground water monitoring program coupled with an extensive hydrogeologic investigation. Determination of ground water flow direction and horizontal and vertical gradients are necessary to assess the direction of potential contaminant migration. Historical data on wastes disposed in specific units can provide information on contaminants likely to be detected downgradient.

Facility Description

This facility was previously described in Case Study 3. Chemicals were manufactured at the 1000-acre facility for over 30 years. The facility produced plastics including cellulose nitrate, polyvinyl acetate, polyvinyl chloride and polystyrenes, and other chemicals such as phenols and formaldehyde. Wastes produced in the manufacturing processes were disposed on site in an unlined liquid waste impoundment and in two solid waste disposal areas. Readily combustible materials were incinerated in four burning pits. Ground water contamination has been documented at the site. Figure 15-33 shows the facility plan and locations of ground water monitoring wells.

The site is located in a glacial valley and is adjacent to a major river. A minor tributary runs through the southwestern portion of the facility and drains into the river. Approximately 200 dwellings are located downgradient of the site.

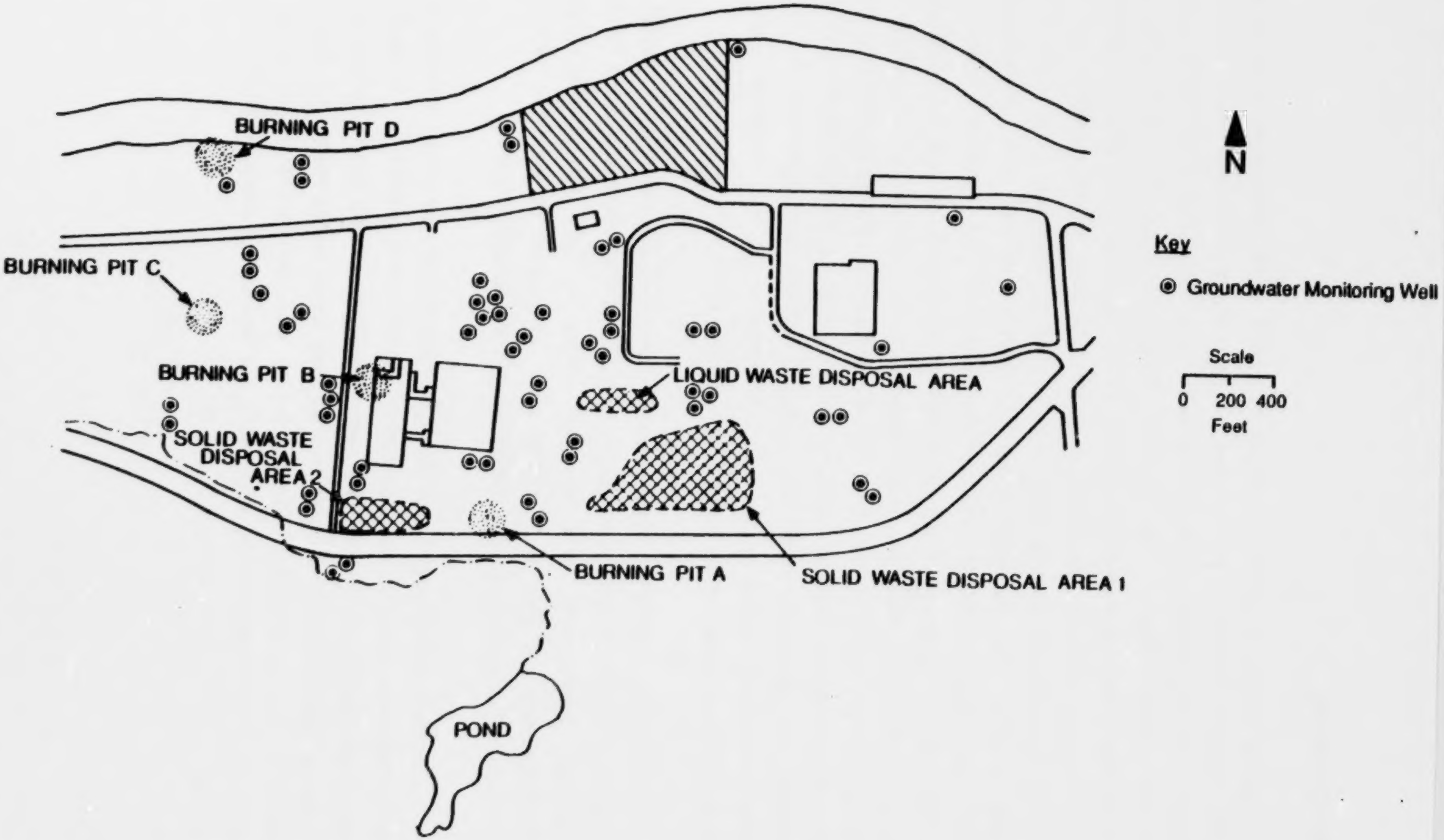

BURNING PIT D
BURNING PIT C
BURNING PIT B
SOLID WASTE DISPOSAL AREA 2
LIQUID WASTE DISPOSAL AREA
BURNING PIT A
SOLID WASTE DISPOSAL AREA 1
POND
N
Key
◉ Groundwater Monitoring Well
Scale
0 200 400
Feet

Figure 15-33. Location of Ground-Water Monitoring Wells

Data Collection

Initial studies to assess the extent of ground water contamination began in 1981. Studies focused on ground water in the vicinity of various waste disposal units. A limited number of monitoring wells were installed in 1983. These wells provided general data on the direction of ground water flow and chemical constituents that had entered the ground water. In 1984, a two-phased approach was developed to define the areal and vertical extent of contamination and to identify contaminant releases from specific waste manaement units. The first phase involved the characterization of facility geologic and hydrogeologic conditions using historical data, determination of the chemical nature of contaminants in the ground water using existing monitoring wells, and development of a contaminant contour map delineating the horizontal boundaries of contamination. Based on this data, 33 soil borings were drilled in Phase 2. The goals of the second phase were: 1) to detail subsurface geologic characteristics, vertical and horizontal water flow patterns, contaminant migration, and site-specific chemical contaminants; and 2) to install wells that would be used to monitor contaminants being released from all units of concern at the facility.

Continuous split spoon samples were collected in each boring and headspace analyses for volatile organic compounds (VOC) were conducted on each sample. Chemical constituents were identified using a field gas chromatograph. Confirmational analysis by GC/MS were conducted on selected samples. Geotechnical analyses were also conducted on the split spoon samples.

Chemical and hydrogeologic data (direction of flow, gradients) obtained from the borings were used to select appropriate ground water monitoring well locations and screen depths. Fifty-two (52) nested monitoring wells were installed at 25 locations upgradient and downgradient of each waste management unit, and near the river and its tributary. Screen depths were determined by the depth of maximum VOC contamination observed in the borings and the permeability of soil layers.

Data Analysis

Ground water contamination data from new wells coupled with historical waste disposal data allowed releases from three specific waste management areas to be defined. Sample analyses showed organic solvents in nearly all locations. However, more unusual constituents associated with specific manufacturing processes were detected in some samples, allowing them to be correleated with releases from specific waste management units. The two situations below illustrate how these correlations were accomplished:

1) PCBs detected in some samples were correlated with Solid Waste Disposal Area #1. This area received construction debris, resins, plastics, metals, drums, and PCB containing transformers. Records indicated that this unit was the only location where transformers were disposed onsite. PCBs could not be associated with any of the other waste management units.

2) The solvent dimethylformamide (DMF) detected in some samples was correlated with Burning Pit B. It was discovered that the building that housed this unit had been used to tint windshields and that DMF is a component of the dye used in this process. DMF could not be tied to any of the other waste management units. A leachfield in which waste dyes had been disposed was discovered under the building and the contamination was traced back to that source.

Case Discussion

An extensive hydrogeologic investigation of the facility was completed and, in conjunction with historical data, was used to develop a comprehensive ground water monitoring program. Placement of the monitoring wells and screens was essential in providing data that unequivocally linked contaminant releases to specific waste management units and manufacturing processes.

CASE STUDY 20: WASTE SOURCE CHARACTERIZATION FROM TOPOGRAPHIC INFORMATION

Points Illustrated

- Mapping of changes in site topography can support the selection of locations for test borings and monitoring wells.
- This technique is best employed at sites where large volumes of waste have been disposed of over several years.

Introduction

Topographic surveys conducted prior to and at different times during the operation of a waste management facility can be used to help characterize the vertical and horizontal extent of waste disposal areas. Because the resolution of this technique is limited, it is most useful when large volumes of waste are involved.

Facility Description

This facility is the same as discussed in case Studies 3, 4, and 18 above.

Topographic Survey

In 1984, a topographic survey measuring elevations in feet relative to mean sea level was conducted for the areas shown in Figure 15-34. These elevations were plotted on a map of appropriate horizontal scale and contoured in 2-foot intervals. This topography was transferred to an existing site plan (horizontal scale 1" to 200'). Topographic maps from 1935 (showing the natural topography before waste deposition) to 1960 (showing the topography in the earlier stages of the facility operation) were compared to the 1984 map. By examining the changes in elevations which occurred over time, contours were developed showing the estimated changes in vertical and horizontal units of the liquid waste and solid waste disposal areas.

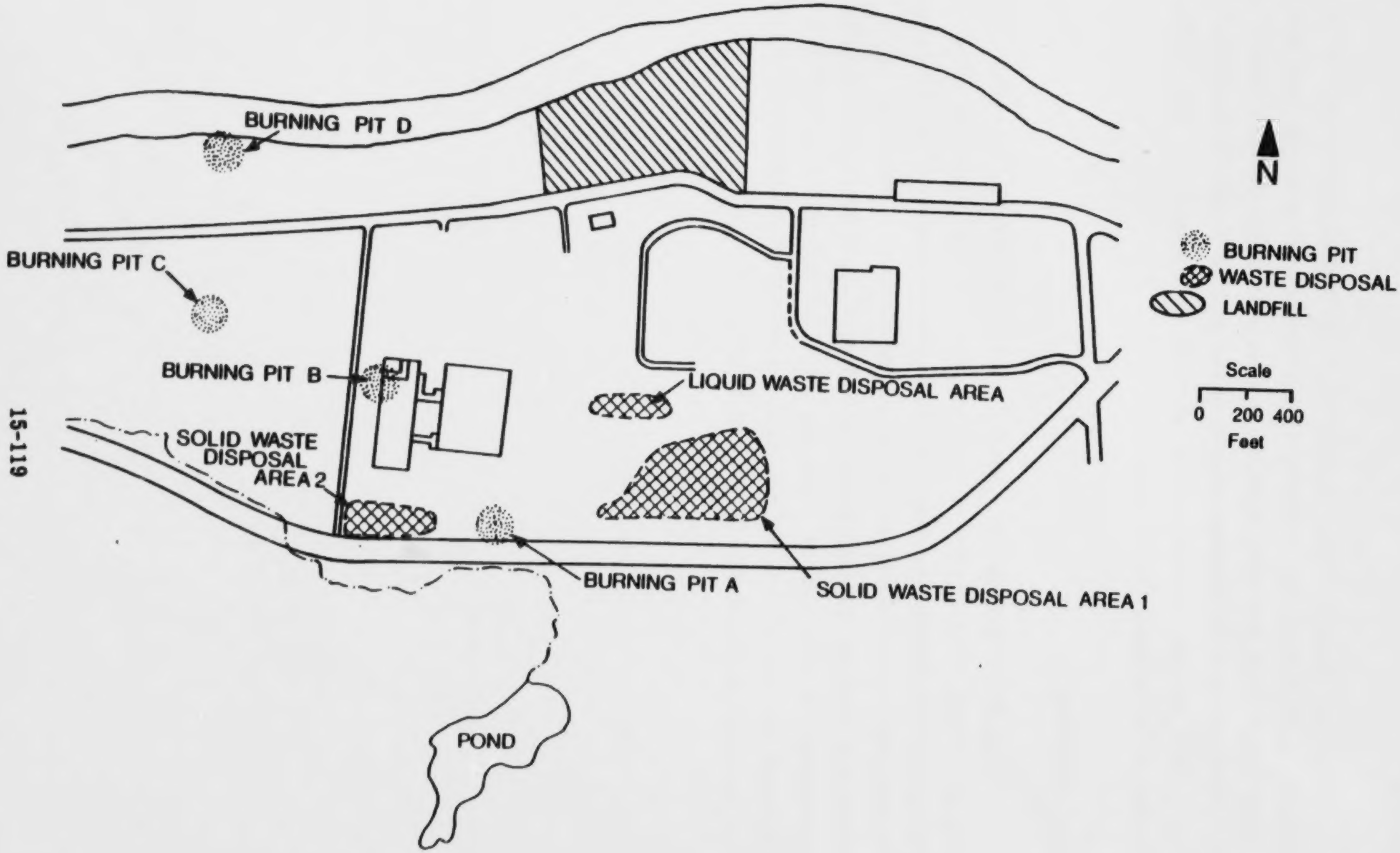

BURNING PIT D
BURNING PIT C
BURNING PIT B
SOLID WASTE DISPOSAL AREA 2
LIQUID WASTE DISPOSAL AREA
BURNING PIT A
SOLID WASTE DISPOSAL AREA 1
POND
N
BURNING PIT
WASTE DISPOSAL
LANDFILL
Scale
0
200
400
Feet

Figure 15-34. Topographic Survey Area and Grid Layout

Results

From the analysis, it was apparent that the deepest portion of Solid Waste Disposal Area (SWDA) No. 1 (Figure 15-34) was approximately 48 feet, and the Liquid Waste Disposal Area (LWDA) was approximately 30 feet deep. The horizontal limits of the disposal areas were also defined in part by this review, but other field surveys provided more accurate information on the horizontal boundaries of the waste disposal areas.

Case Discussion

Topographic surveys can provide useful information for characterizing disposal areas. The results of these studies can facilitate the selection of appropriate test boring locations, and may reduce the number of borings necessary to describe the subsurface extent of contamination. It should be noted that techniques such as infrared aerial photography and topographic surveying are approximate in their findings. They are useful methods in the early phases of an investigation, but do not replace the comprehensive characterization of the environmental setting needed for the full investigation.

CASE STUDY 21: SELECTION OF GROUND WATER MONITORING PARAMETERS BASED ON FACILITY WASTE STREAM INFORMATION

Points Illustrated

- Waste stream information can be used to identify potential contaminants. Knowing this, ground water monitoring parameters can be selected appropriately.

- The number of constituents analyzed may be significantly reduced from Appendix VIII (40 CFR Part 261) constituents when waste stream information is available.

Introduction

Regulated treatment, storage, and disposal facilities are required by RCRA to identify all waste streams handled by the facility, volumes handled, concentrations of waste constituents, and the waste management unit in which each waste type is disposed. Ground water monitoring programs must be developed to adequately monitor contaminant migration from each unit. Constituents to be analyzed in the ground water monitoring program must be established prior to sample collection. When waste stream data are not availble, a standard set of monitoring constituents (Appendix VIII) are employed to fully characterize any ground water contamination. Appendix VIII includes numerous constituents, so the corresponding analyses are time consuming and costly to perform. Knowledge of the waste streams managed by a facility simplifies the selection of indicator parameters and monitoring constituents because potential contaminants and their likely reaction and degradation products can be identified, thereby eliminating the need for analyzing all Appendix VIII constituents.

Facility Description

The 600-acre facility has operated as a permitted Class II-I waste disposal site since 1980. Solid waste management units occupy 20 acres of the site and include four RCRA regulated surface impoundments and one container storage area. Until 1985, three non-RCRA regulated units (two surface impoundments and one solids disposal unit) were used for geothermal waste disposal. However, the two surface impoundments were replaced by a RCRA regulated landfill. RCRA wastes managed by the facility include: metals, petroleum refining wastes, spent non-halogenated solvents, electroplating waste water treatment sludge, spent pickle liquor from steel finishing operations, and ignitable, corrosive, and reactive wastes. Ground water monitoring wells have been installed downgradient of each waste mangement unit.

Program Design

Prior to disposal, each load of waste received is analyzed in an on-site laboratory to provide a complete characterization of waste constituents. Periodic sampling of the waste management units is also conducted to identify waste reaction products and hazardous mixtures. Even though the incoming wastes have been characterized, the facility owner also analyzed initial ground water samples from each monitoring well for all Appendix VIII constituents. The resulting data were used to establish existing concentrations for each constituent and to select a set of indicator parameters. The latter are used to identify migration of waste to the ground water system. Table 15-15 includes a list of the indicator parameters analyzed at the facility. Rationale for parmeter selection are included in this table.

When an increase is detected in any of the indicator parameters, the facility is required to monitor immediately for Appendix VIII constituents. Because the facility accepts only a limited number of Appendix VIII constituents and initial monitoring verified the absence of many constituents, this facility has been allowed to reduce the total number of constituents monitored in ground water. The process of constituent elimination is dependent on the actual wastes received by the facility and physical and chemical properties of constituents that influence their migration potential (e.g., octanol/water partition coefficients, solubility, adsorptivity, susceptiblity to biodegradation).

TABLE 15-15

INDICATOR PARAMETERS

Parameter	Criteria for Selection
Total Organic Carbon (TOC)	Collective measure of organic substances present
Total Petroleum Hydrocarbons	Indication of petroleum waste products
Total Organic Halogen (TOX)	Halogenated organic compounds are generally toxic, refractory, and mobile
Nitrates	Mobile contaminant, degradation product of nitrogen compounds, mold, ammonia
Chloride	Plating solution constituent, highly mobile in ground water. Early indicator of plume arrival
Sulfides	Toxic, biodegradation by product, strong reducing agent, may immobilize heavy metals
pH	Good indicator of strongly acidic or alkaline waste leachates close to sources
Total phenols	Collective measure of compounds likely to be in waste. Even small concentrations can cause olifactory problems following water treatment by chlorination

Non-halogenated solvents have relatively low partition coefficients (K_{ow}: benzene = 100; toluene = 500) and are not readily retained by soils. Conversely, polycyclic aromatic hydrocarbons, constituents of petrochemical wastes, have very high partition coefficients (e.g., chrysene = $4x10^5$) and are generally immobile in soils. Migration rates of metals are also influenced by the exchange capacity of the soil. Different metal species are retained to different extents. Following an assessment of the migration potential of each waste constituent, the need for analysis of that constituent can be prioritized. Two waste types never accepted at the subject site include halogenated solvents and pesticides. Therefore, constituents found in these wastes would be de-emphasized.

Case Discussion

Waste stream information was used to determine appropriate indicator parameters and monitoring constituents. The use of the existing initial ground water quality data and the incoming waste analyses allowed for prediction of contaminants of concern in ground water and reduced the number of constituents requiring analysis.

CASE STUDY 22: USING WASTE REACTION PRODUCTS TO DETERMINE AN APPROPRIATE MONITORING SCHEME

Point Illustrated

- It is important to consider possible waste reaction products when designing a monitoring plan.

Introduction

Volatile organic priority pollutants have been detected in ground water all across the country. These compounds, widely used as solvents, are generally considered environmentally mobile and persistent. Increasing evidence, however, indicates that chlorinated solvents can be degraded under anaerobic conditions by reductive dehydrochlorination. The sequential removal of chlorine atoms from halogenated 1 and 2 carbon aliphatic compounds results in formation of other volatile priority pollutants which can be detected during investigations of solvent contamination.

Facility Description

The facility is a small municipal landfill sited on a former sand and gravel quarry. In addition to municipal wastes, the landfill accepted trichloroethane and tetrachloroethene contaminated sludge from a local fabrication plant until 1975. In 1983, a municipal well located downgradient from the landfill tested positive for dichloroethane, dichloroethene isomers, and vinyl chloride. This prompted the city to investigate the cause and extent of the problem.

Site Investigation

According to records kept at the landfill, some of the compounds found in the municipal well were not handled at the facility. This prompted the city to request that a monitoring program be developed to identify another facility as the source of the well contamination. A careful search of the city records, however, failed to indicate a credible alternative source of the compounds. Suspecting that the landfill was the source of the well contaminants, five monitoring wells were installed (Figure 15-35) and water samples were analyzed for halogenated compounds using EPA Method 601. The results, given in Table 15-16, show an increase in degradation products of trichloroethane and tetrchloroethene with increasing distance from the landfill. Using these data, supported by hydrogeologic data from the monitoring wells, the municipal landfill was shown to be the source of the observed contamination.

Table 15-16

RESULTS OF MONITORING WELL SAMPLING

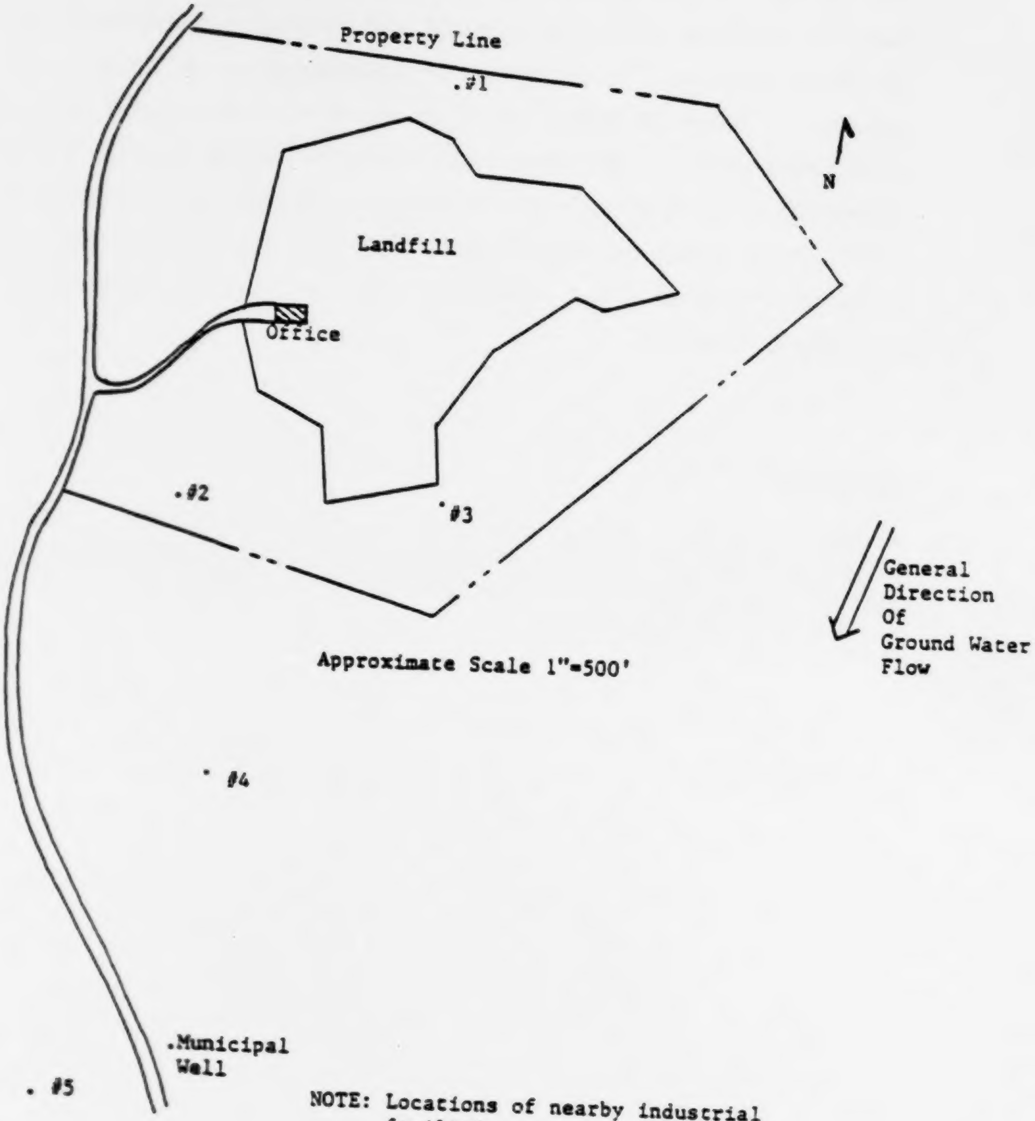
	WELL NUMBER (SEE FIGURE 2-34 FOR WELL LOCATIONS)				
	1	2	3	4	5
Chlorinated Ethanes					
(1) Trichloroethanes	10(3)	68	ND(4)	ND	ND
(2) 1,1-Dichloroethane	71	240	130	11	13
1,2-Dichloroethane	ND	12	21	ND	ND
Chloroethane	ND	21	18	160	ND
Chlorinated Ethenes					
(1) Tetrachloroethene	80	13	ND	ND	ND
Trichloroethene	12	100	62	ND	ND
(2) 1,2-Dichloroethenes	ND	990	950	150	ND
1,1-Dichloroethene	ND	ND	ND	ND	ND
Vinyl Chloride	ND	120	59	100	ND

(1) Parent Compounds
(2) Degradation Products

(3) All Concentrations In Micrograms/L
(4) ND - < 10 Micrograms/L

Case Discussion

Based on the compounds found in the municipal well, the city had argued that the municipal landfill could not be the source of the contamination. If this reasoning had been followed, then a system of monitoring wells might have been inappropriately designed in the attempt to find an alternate source of


Property Line
.#1
N
Landfill
Office
.#2
#3
General
Direction
Of
Ground Water
Flow
Approximate Scale 1"=500'
#4
.Municipal
Well
. #5

NOTE: Locations of nearby industrial
facilities not shown.

Figure 15-35. Site Map and Monitoring Well Locations

the contamination. Instead, after carefully researching local industries, it was determined that the landfill was the most reasonable source of the pollution and that the observed well contaminants were probably degradation products of the landfilled solvents. The progressive dehalogenation of chlorinated ethanes and ethenes, as listed in Table 15-16, is commonly encountered in situations where chlorinated solvents are subjected to anaerobic conditions (Wood, 1981). Different degradation reactions may occur when pesticides are subjected to acidic or alkaline conditions or biological degradation. Therefore, it is important to keep reaction products in mind when designing any monitoring scheme or interpreting contamination data.

Reference

Wood, P.R., R.F. Lang, I.L. Payan, and J. DeMarco. 1981. Anaerobic Transformation, Transport and Removal of Volatile Chlorinated Organics in Ground Water. First International Conference on Ground Water Quality Research, October 7-10, 1981, Houston, Texas.

CASE STUDY 23: USE OF AERIAL PHOTOGRAPHY TO IDENTIFY CHANGES IN TOPOGRAPHY INDICATING WASTE MIGRATION ROUTES

Points Illustrated

- Aerial photographs can be used to obtain valuable data on facility-related topographic features including type of waste disposal facility, distance to residences and surface waters, adjacent land use, and drainage characteristics.

- Detailed interpretation of aerial photographs can identify actual and potential waste migration routes, and areas requiring corrective action.

Introduction

Stereoscopic pairs of historical and current aerial photographs were used to assist in the analysis of waste management practices at a land disposal facility. Stereo viewing enhances the interpretation of aerial photographs since vertical as well as horizontal spatial relationships can be observed, and since the increased vertical resolution aids in distinguishing various shapes, tones, textures, and colors within the study area. Typical items that should be noted include pools of unexplained liquid that could indicate seepage from buried materials which could enter drainage and migrate off site. Soil discoloration and vegetation damage or lush vegetation growth can be indicative of how materials are being handled on site and of possible off-site contaminant migration.

Facility Description

The site is an active land disposal facility which receives bulk hazardous waste including sludges and contaminated soil for burial, and liquid wastes for disposal into solar evaporation surface impoundments. Operations at the facility began in 1969. Historical and current aerial photographs were reviewed to assess waste management practices and to identify potential contaminant migration pathways requiring further investigation and corrective action.

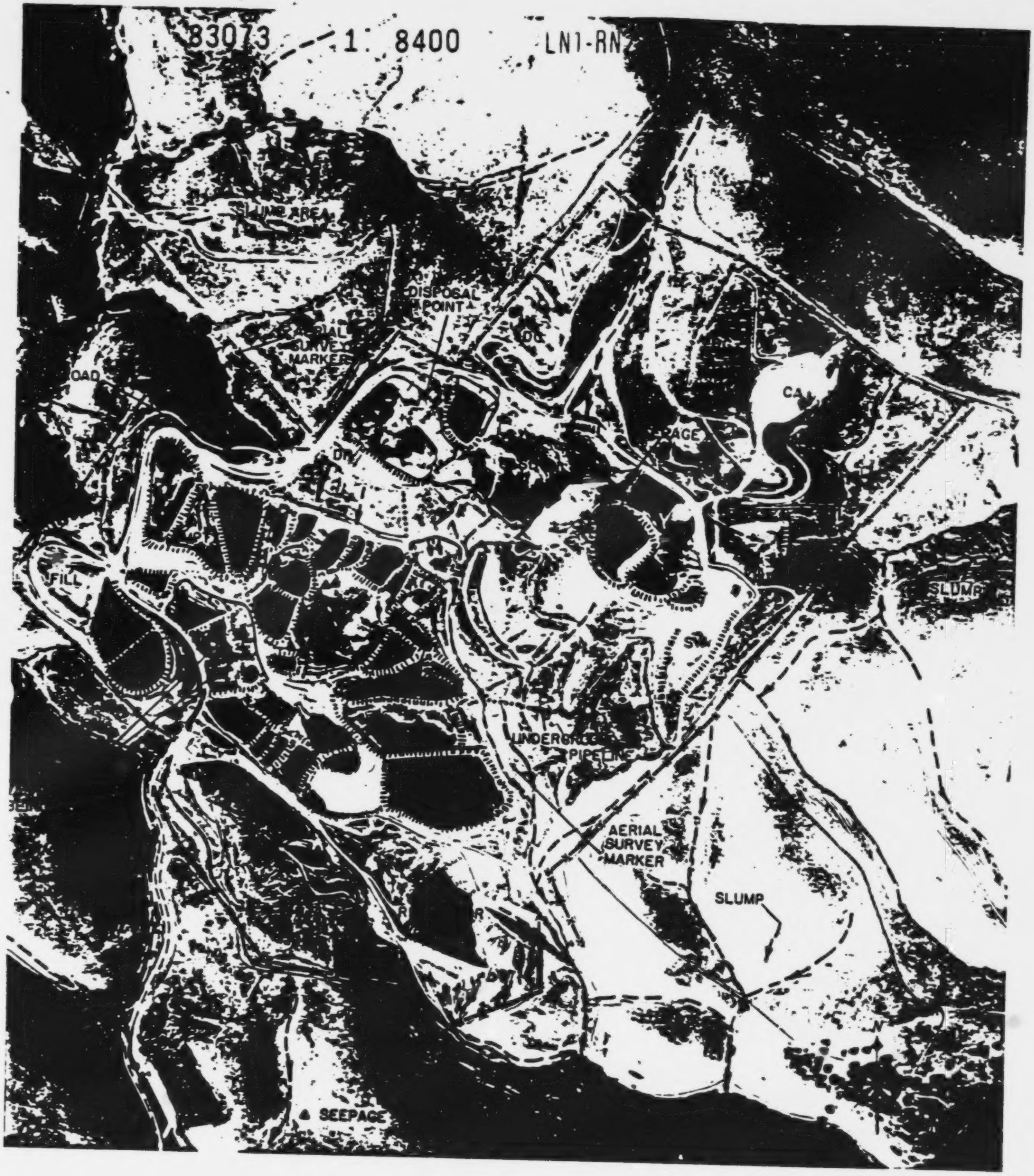
Data Collection and Anaysis

Low altitude color aerial photographs of the facility (scale = 1:8400) were obtained in October 1983 and Feburary 1984. The photos were interpreted by an aerial photo analyst at the U.S. EPA Environmental Monitoring and Support Laboratory at Las Vegas, Nevada. Figure 15-36 shows the analyzed photograph. The interpretation code is given in Figure 15-37. Analysis of the photograph indicates several areas of seepage at the base of the surface impoundments. This seepage indicates that either the impoundments are not lined or the liners have failed. Drainage from the western portion of the facility which contains most of the impoundments flows into a drainage reservoir formed by a dam across the main drainage. Drainage from the northeast portion of the facility where seepage was also observed appears to bypass this reservoir and enter the main drainage which flows offsite. Besides possible surface contamination, this seepage also indicates potential subsurface contamination.

The aerial photo obtained in February 1984 (Figure 15-38) indicates the continued existence of seepage from the surface impoundments. There is evidence of possible discharge from the drainage reservoir to a stream channel, as a pump and piping were observed. Additional material in the solid waste disposal area has altered the drainage pattern. At the south end of this area, seepage is evident in association with damaged vegetation. Drainage from this area enters a drainage system and appears to be diverted offsite.

Case Discussion

Analysis of aerial photographs of the land disposal facility enabled investigators to identify potential contaminant sources and migration pathways. This information was used by investigators to identify areas for surface water, sediment, soil, and subsurface sampling. Most importantly, it identified areas requiring corrective action including impoundment liners and the facility drainage system.


83073 1: 8400 LN1-RN
SLUMP AREA
DISPOSAL POINT
AERIAL SURVEY MARKER
OAD
FILL
SLUMP
UNDERGROUND PIPELINE
AERIAL SURVEY MARKER
SLUMP
SEEPAGE

Reproduced from best available copy.

Figure 15-36. October 1983 Aerial Photo of Land Disposal Facility

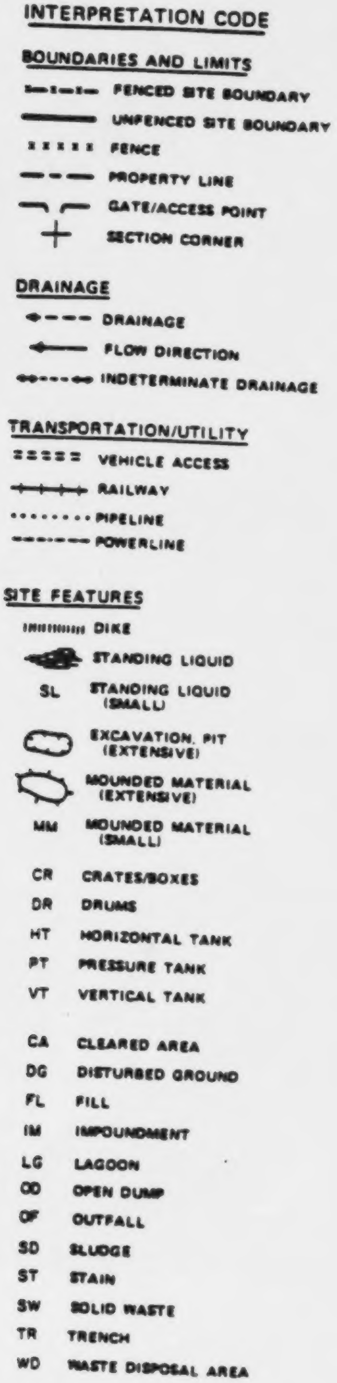

INTERPRETATION CODE
BOUNDARIES AND LIMITS
FENCED SITE BOUNDARY
UNFENCED SITE BOUNDARY
FENCE
PROPERTY LINE
GATE/ACCESS POINT
SECTION CORNER
DRAINAGE
DRAINAGE
FLOW DIRECTION
INDETERMINATE DRAINAGE
TRANSPORTATION/UTILITY
VEHICLE ACCESS
RAILWAY
PIPELINE
POWERLINE
SITE FEATURES
DIKE
STANDING LIQUID
SL STANDING LIQUID (SMALL)
EXCAVATION, PIT (EXTENSIVE)
MOUNDED MATERIAL (EXTENSIVE)
MM MOUNDED MATERIAL (SMALL)
CR CRATES/BOXES
DR DRUMS
HT HORIZONTAL TANK
PT PRESSURE TANK
VT VERTICAL TANK
CA CLEARED AREA
DG DISTURBED GROUND
FL FILL
IM IMPOUNDMENT
LG LAGOON
OD OPEN DUMP
OF OUTFALL
SD SLUDGE
ST STAIN
SW SOLID WASTE
TR TRENCH
WD WASTE DISPOSAL AREA

Figure 15-37. Aerial Photo Interpretation Code

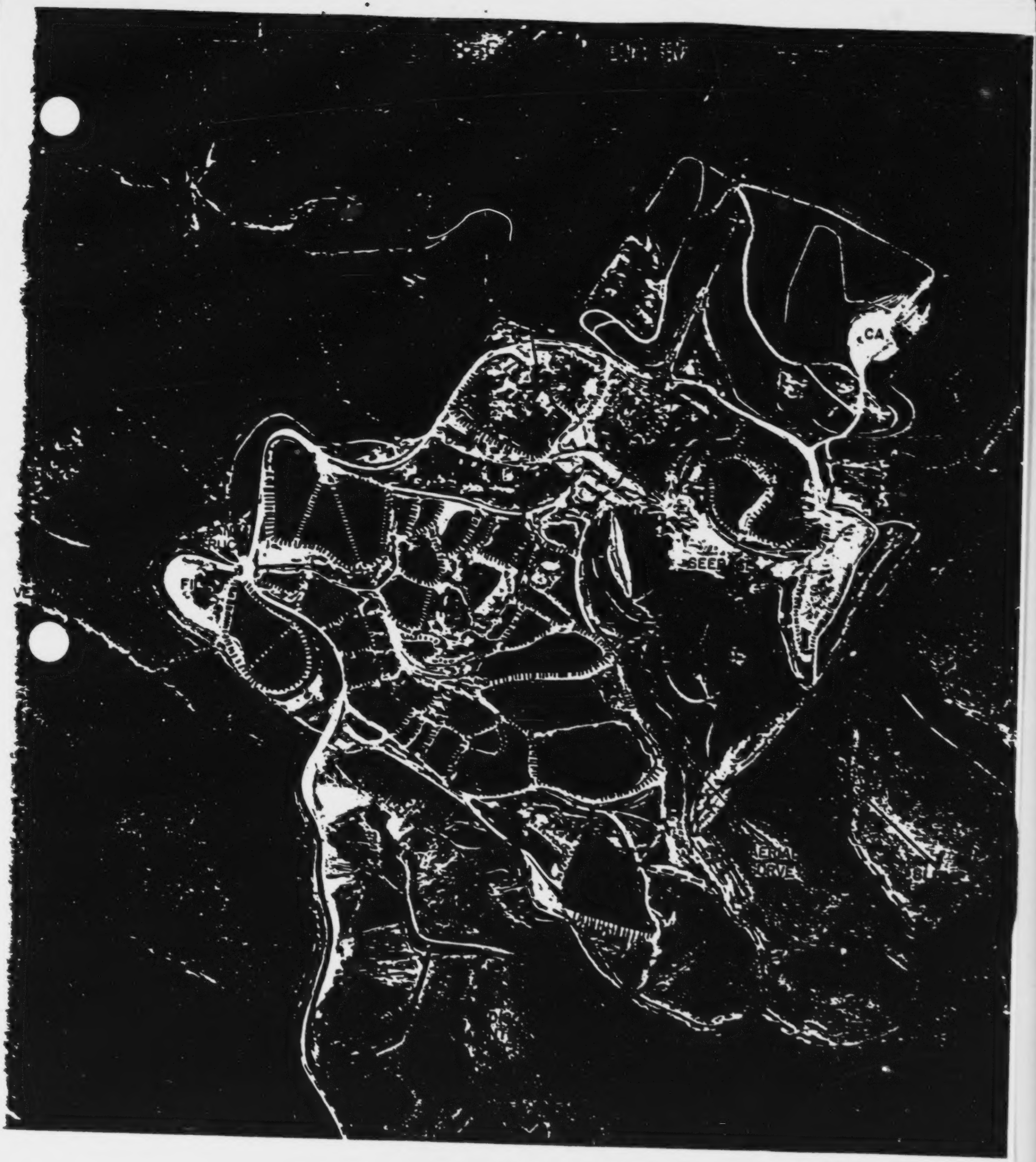


Figure 15-38. February 1984 Aerial Photo of Land Disposal Facility

CASE STUDY 24: IDENTIFICATION OF A GROUND WATER CONTAMINANT PLUME USING INFRARED AERIAL PHOTOGRAPHY

Point Illustrated

- Infrared photography can assist in identifying plumes and in locating monitoring wells by showing areas of stressed vegetation and contaminated surface water.

Introduction

Infrared aerial photography can assist in identifying contaminant plumes at sites where little or no monitoring has been conducted. By identifying areas of stressed vegetation or contaminated surface water, it may be possible to focus on contaminant discharge points and roughly define the extent of a release. Hydrogeologic investigations and surface water sampling can then be performed to further characterize the release. Considering the expense of drilling and installing wells, infrared photography offers the potential to increase the efficiency of a sampling program.

Facility Description

The facility is a municipal solid waste landfill which has served a population of 22,000 for 30 years. The facility covers an area of 11 acres, holding an estimated 300,000 tons of refuse. The majority of waste in the landfill was generated by the textile industry. Until July 1978, the facility was operated as an open dump with sporadic management. City officials indicated that original disposal occurred in open trenches with little soil cover. After July 1978, the facility was converted to a well-operated sanitary landfill. Figure 15-39 shows the facility.

Geologic Setting--

The landfill is located on a sandy to silty till varying in thickness from 23 feet at the hill crest to 10 feet on the side slope. A swamp is present at the base of the hill at about 255 feet above sea level. There is a dam at the southern drainage outlet of the swamp, a distance of 2,500 feet from the landfill. Ground

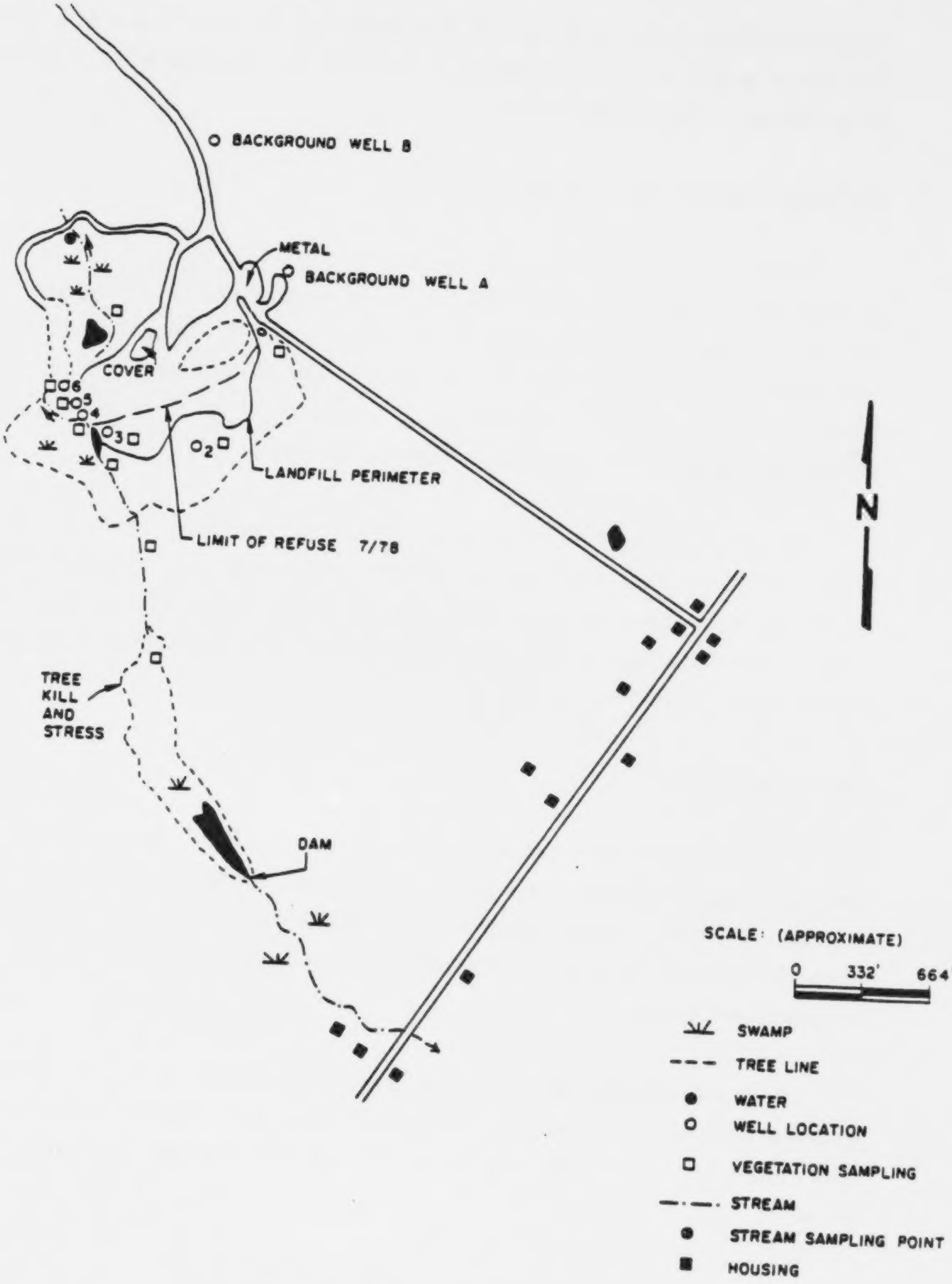

BACKGROUND WELL B
METAL
BACKGROUND WELL A
COVER
6
5
4
3
2
LANDFILL PERIMETER
LIMIT OF REFUSE 7/78
N
TREE KILL AND STRESS
DAM
SCALE: (APPROXIMATE)
0
332'
664'
SWAMP
TREE LINE
WATER
WELL LOCATION
VEGETATION SAMPLING
STREAM
STREAM SAMPLING POINT
HOUSING

Figure 15-39. Facility Plan

water is approximately 20 feet below the surface at the crest of the hill, while on the slope it is at 6 feet. The swamp at the foot of the hill is the surface expression of the ground water (Figure 15-40).

Aerial Photography and Sampling Program

Figure 15-41 shows the infrared aerial image of the site. The landfill corresponds to the light area in the northwest portion of the photograph (Figure 15-40). The dark area to the south of the site is stressed vegetation, and the light area within it is contaminated swamp water. The 33-acre area of tree kill and stress is clearly visible. Plants under stress may be detected by infrared photography because of changes in infrared reflectance.

Ground water monitoring wells and vegetation sampling points are shown in Figure 15-39. Data collected from the wells indicated elevated levels of chromium, manganese, iron, and total organic carbon (TOC). Table 15-17 lists the average concentrations of the parameters tested. The vegetation study indicated an accumulation of heavy metals.

Case Discussion

The vegetative stress apparent in the infrared photography was confirmed by the data from the ground water and vegetation sampling. However, the site requires further characterization to determine vertical boundaries of contamination and to assess the potential for impact beyond the present area of stressed vegetation.

It should be emphasized that infrared photography is not a substitute for hydrogeologic characterization. However, it is a useful tool for identifying areas of stressed vegetation that may be associated with releases from waste disposal sites.

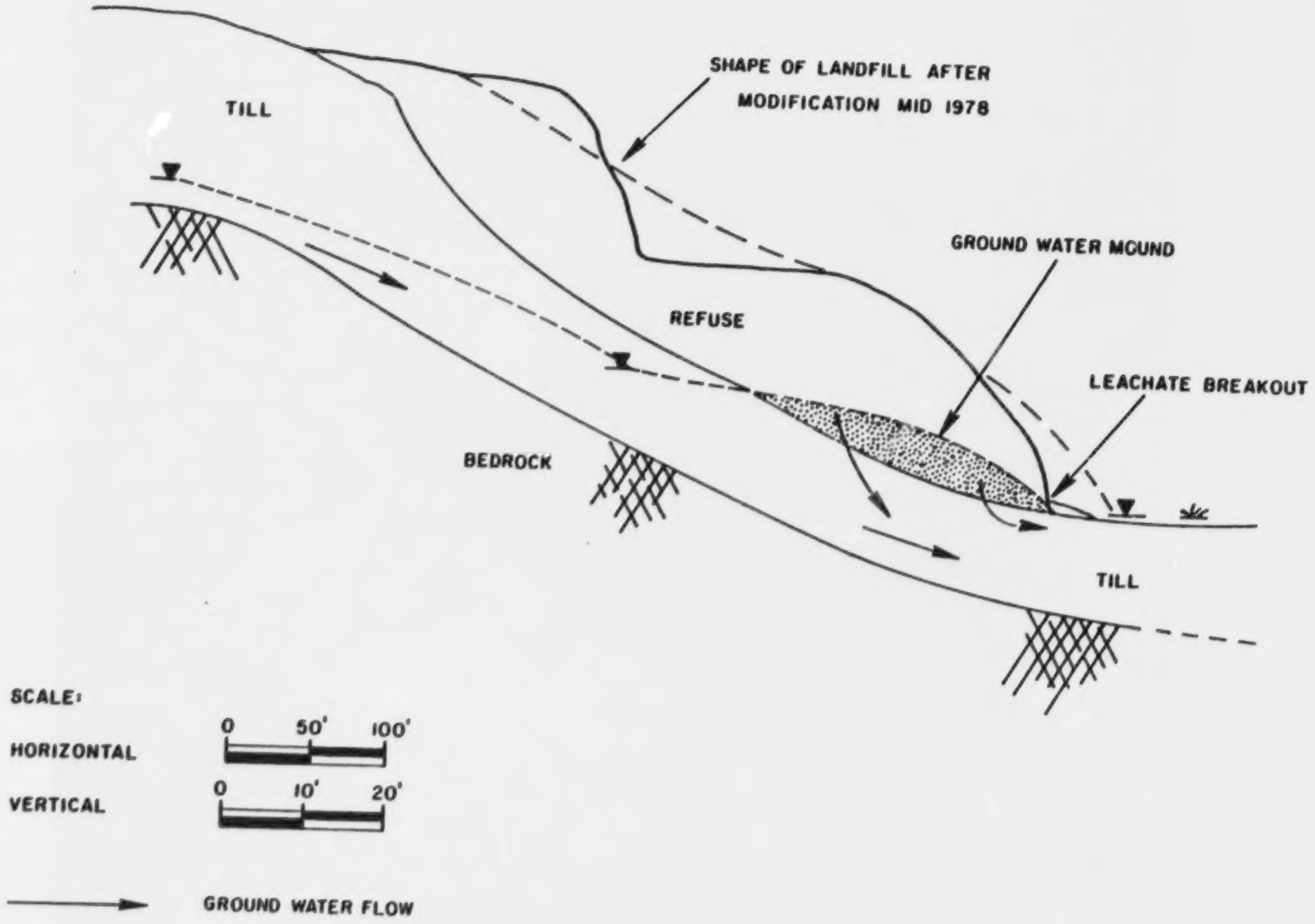

SHAPE OF LANDFILL AFTER MODIFICATION MID 1978
TILL
GROUND WATER MOUND
REFUSE
LEACHATE BREAKOUT
BEDROCK
TILL
SCALE:
HORIZONTAL
0
50'
100'
VERTICAL
0
10'
20'
GROUND WATER FLOW

Figure 15-40. Generalized Geologic Cross-Section

Reproduced from
best available copy.

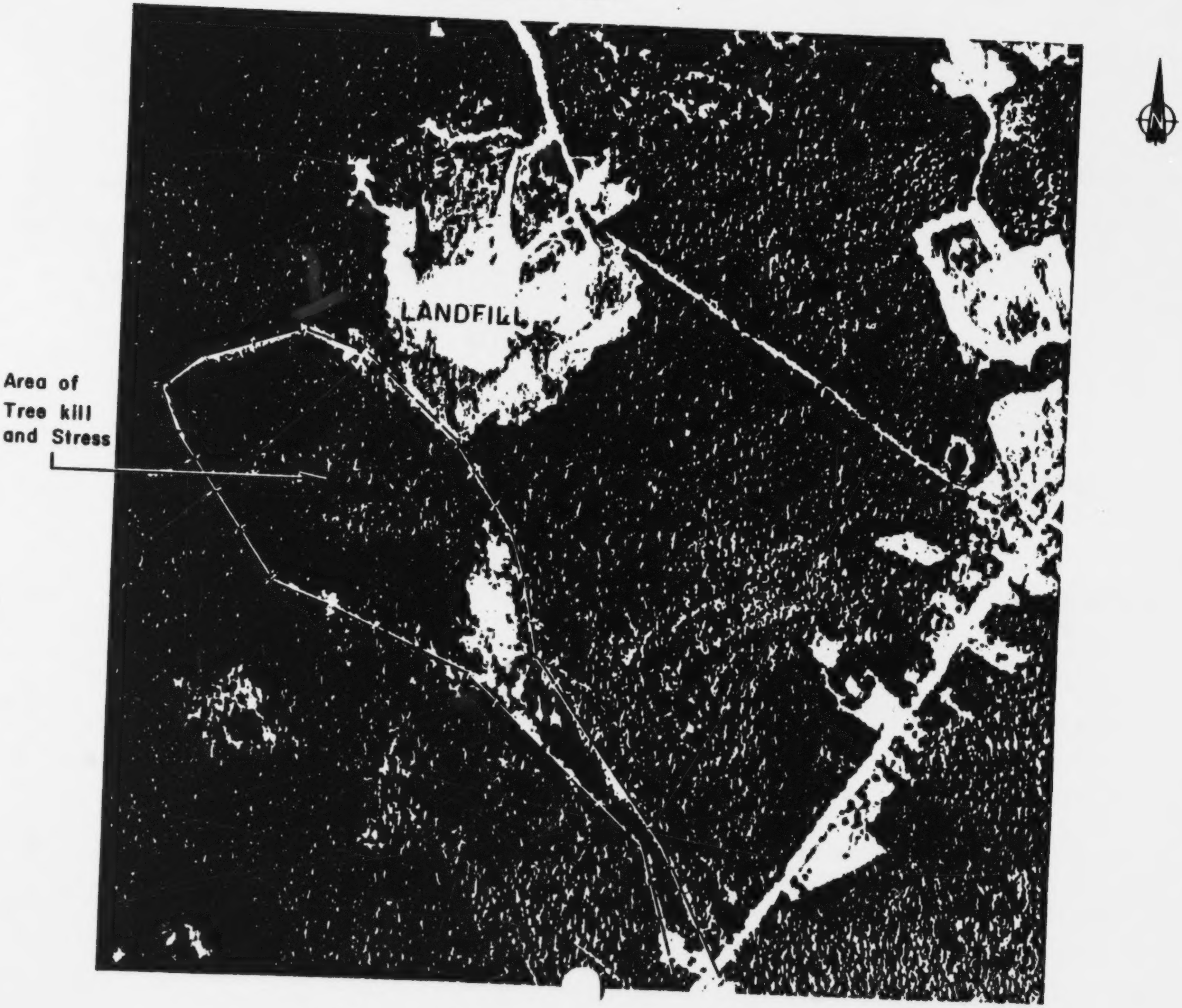

LANDFILL
Area of
Tree kill
and Stress
N

Figure 15-41. Infrared Aerial Photograph of the Site

TABLE15-17

AVERAGE VALUES OF PARAMETERS IN GROUND WATER AND STREAM SAMPLES[1]

	BOD_5	TOC	TKN	NH_3	NO_3 =	To.P	Fe	Mn	Hardness	Cl	ClBD	Cr	TDS	Cd	pH
Background[2]	<10	/	/	/	/	1.73	2.7	0.4	18.2	5.2	102	/	98	0.05	/
Well #2	<20	119	1.7	0.54	0.48	0.11	108.8	4.2	525.6	67.3	1000	0.03	828.5	T	2.9
Well #3	<20	56	5.5	3.9	0.10	0.15	39.6	16.3	414.2	103.5	450	0.02	230	---	5.5
Well #4	/	300	2.5	<0.01	<0.01	0.13	27	9.4	1	980		0.02	/	/	5.4
Well #5	20	45.5	0.6	1.22	0.15	0.18	71.6	3.8	353	74.7	240	0.03	863.0	T	5.8
Well #6	19	45.5	3.4	2.47	<0.1	1.5	177	7.65	659.9	120	1300	0.71	780	/	5.7
Stream	<20	72.5	43.7	49.7	0.05	0.10	18.4	1.73	230	76.7	1300	0.017	817	/	6.8

[1] All values as mg/l, except conductivity (µmhos) and pH (standard units)

[2] Average of background wells A and B

CASE STUDY 25: PRESENTATION OF DATA COLLECTED DURING FACILITY INVESTIGATIONS

Point Illustrated

- Techniques for presentation of data for facility investigations involving multimedia contamination.

Introduction

Data acquisition and interpretation are integral parts of facility investigations. Depending on the size, complexity, and hazards posed at a particular site, significant quantities of meteorologic, hydrologic, and chemical data can be collected. To make the best use of these data, they should be presented in an easily understood and meaningful fashion. This case study focuses on widely used and easily implemented graphical techniques for data presentation.

Site Description

The site is a former copper smelter that ceased operation in the early 1980's. During the operation of the smelter, large quantities of mine tailings were slurried to tailings ponds that remain today (Figure 15-42). The tailings contain high solid phase concentrations of inorganic contaminants such as copper, zinc, lead, cadmium, and arsenic. In the Smelter Hill area, flue dust and stack emission deposition have contaminated surficial soils. Numerous other facilities were operated at the complex including an experimental plant designed to leach copper using ammonia. The copper leach plant is shown in Figure 15-43. Three disposal ponds (I, II, and III) received wastes slurried from the plant.

As a result of smelting and waste disposal practices, multimedia contamination of ground water, surface water, and soils has occurred. Also, episodes of air contamination have been documented due to entrainment of tailings during windy periods.

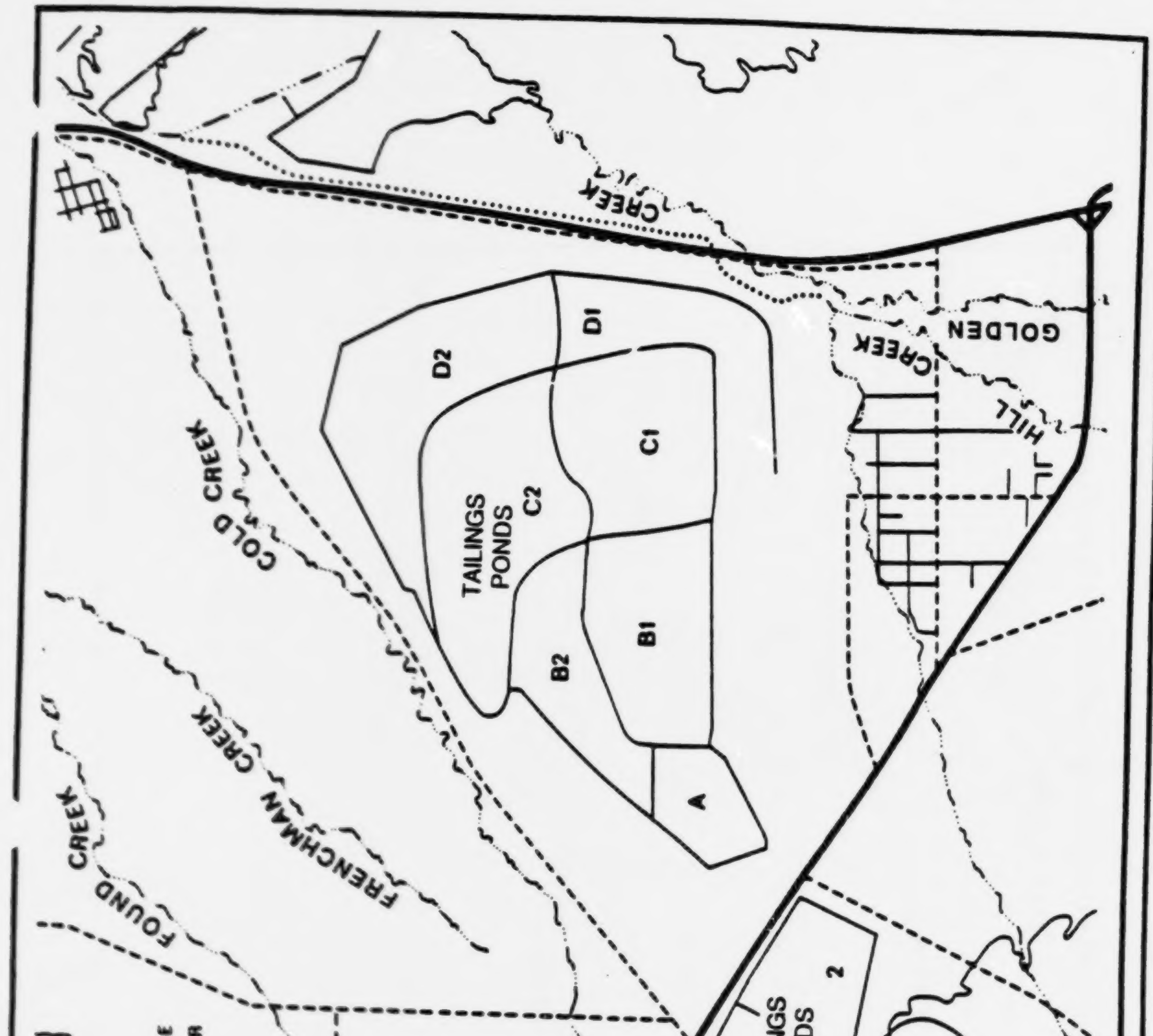

N
0 1 MILE
0 1 KILOMETER
FOUND CREEK
FRENCHMAN CREEK
COLD CREEK
TAILINGS PONDS
A
B1
B2
C1
C2
D1
D2
GOLDEN HILL CREEK
CREEK
TAILINGS PONDS
1
2
SMELTER HILL
STACK

Figure 15-42. Map of the Smelter Site and Associated Tailings Ponds.

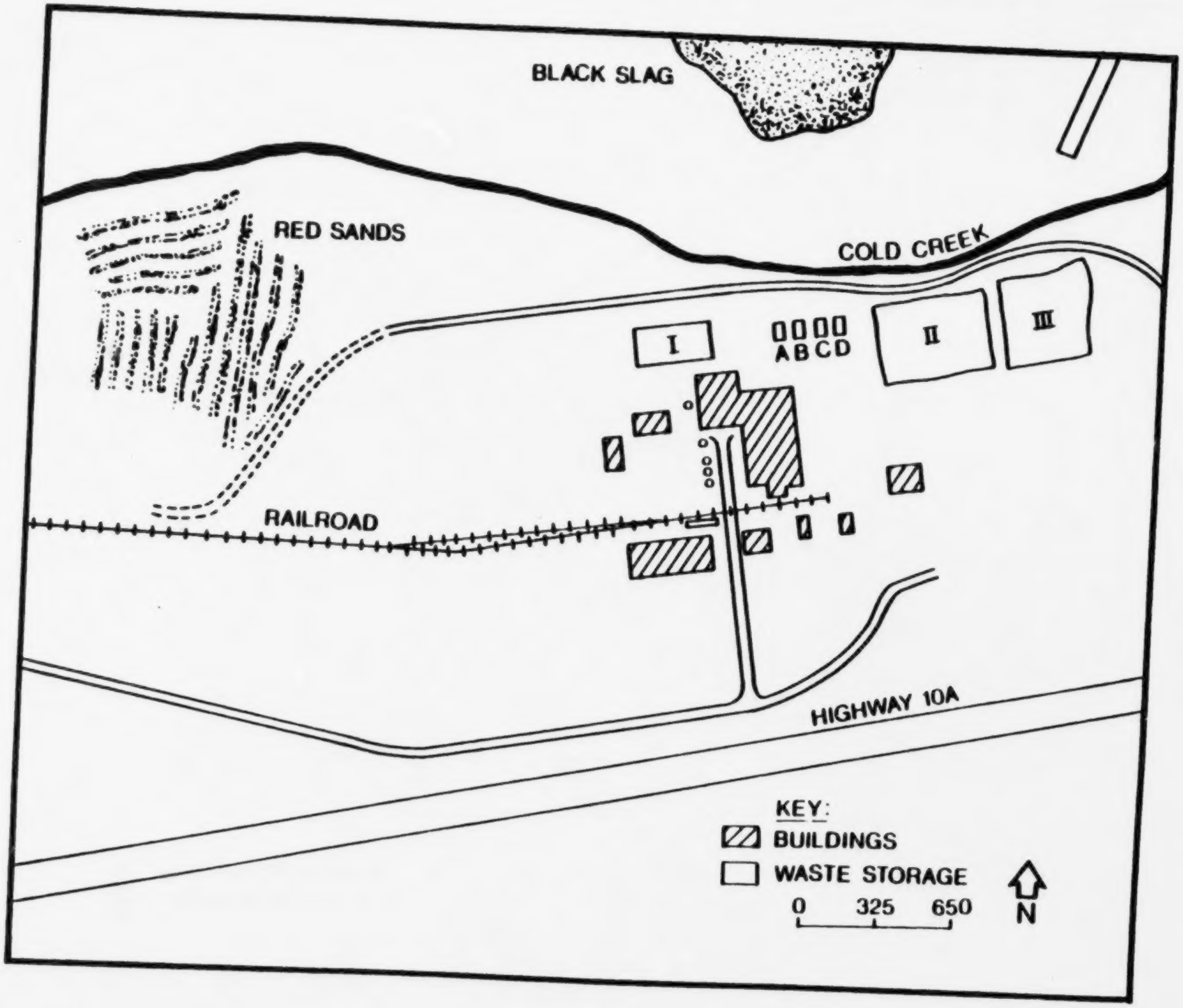

BLACK SLAG
RED SANDS
COLD CREEK
I
A B C D
II
III
RAILROAD
HIGHWAY 10A
KEY:
▨ BUILDINGS
☐ WASTE STORAGE
0 325 650
N

Figure 15-43. Locations of Copper Leach Plant and Waste Storage Ponds

Field Sampling and Data Collection

Data collection activities at this site were comprehensive. Over 100,000 pieces of data were collected in the categories shown in Table 15-18.

Data Presentation

This section illustrates a number of graphical techniques that can be used to present data from facility investigations. Graphical presentations are useful for the following general purposes:

- Site feature identification, source identification, and mapping;
- Hydrologic characterization; and
- Water quality characterization.

For large sites, aerial photography is often very useful for accurately pinpointing the locations and boundaries of waste deposits, and for establishing time variability of site characteristics. Figure 15-43, for example, was developed from aerial photographs at a 1:7800 scale. Types of information obtained by comparing this photograph to one taken 10 years earlier include:

- Pond III was originally constructed earlier than Ponds I and II, and was not lined. Ponds II and III were lined.
- The red sands (a slag deposit) shown in Figure 15-43 are present only north of the railroad tracks. Earlier photographs showed that the red sands extended to Highway 10A, but were leveled and covered with alluvium during construction of the copper leach plant.

This type of photographic information is valuable for locating waste deposits, estimating quantities of wastes, and determining their proximity to sensitive areas.

Table 15-18

SUMMARY OF DATA COLLECTED

Category	Parameters
Ground Water	Water level elevations, piezometric heads
	Concentration of Al, Sb, As, Ba, Be, Bo, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Hg, Mo, Ni, K, Se, Ag, Na, Sn, V, Zn, P, Cl, F, SO_4, pH, O_2, Ec, Eh, Alkalinity, TDS,
Surface Water and Sediment	Flow rates, bed particle size distributions, suspended solids concentrations, dissolved concentrations of same inorganic parameters as ground water
Alluvium[a]	Moisture content, soil pH, Ec, Sb, As, Cd, Cu, Fe, Pb, Mn, Se, Ag, Zn, particle-size distribution
Soil[a]	Cd, Cu, Fe, Pb, Mn, Ni, Zn, Sb, As, Cd, Cr, Hg, Se, Ag, Zn, particle-size distribution, Eh, S, TOC
Tailings[a]	Sb, Ar, Be, Cd, Cu, Fe, Pb, Mn, Ag, Se, Zn, particle size, moisture, pH, Ec, sulfur, carbonate
Slag and Flue Dust[a]	Sb, As, Cd, Cu, Fe, Pb, Mn, Se, Ag, Zn, SO_4, Ec, pH, alkalinity
Miscellaneous	Meteorology, aerial photographs and other photographic documentation, well log data, surface topography, volumetric surveys of waste piles

---

[a] Element data are solid phase.

For sites with complex hydrologic interaction, it is often helpful to graphically represent the flow system. Figure 15-44 illustrates the surface water system at the site. The diagram is useful because it shows the hydrologic interconnections of the drainage system.

For the ground water system, flow direction and velocities provide information needed for solute transport predicitons. This information is generated by plotting water levels on a site map, and then drawing contours through points of constant elevation. An example is shown in Figure 15-45. Because the contours form a regular pattern, they are easily drawn by hand. However, computer-based contour packages exist that could be used to plot more complicated contour patterns.

Inferred flow directions are also shown in Figure 15-45. From a knowledge of the water surface gradient and aquifer permeability, the Darcy and seepage velocities can be calculated, as shown in the upper left hand corner of the figure. A seepage velocity of 80 m/yr is calculated, for example, which means that approximately 125 years would be required for conservative solutes to move across the site.

Water quality data can be presented as shown in Figure 15-46. This figure shows the spatial distribution of calcium, sulfate, and TDS at key surface water stations. This data presentation method provides a synoptic view of these parameters.

Time series plots are useful for showing temporal variations in water quality. For example, time trends of $SO_4^=$ at three ground water locations are shown in Figure 15-47. Well 19 is slightly downgradient from the source, and the high $SO_4^=$ levels reflect that the well is receiving solutes generated within the source. Wells 26 and 24 are further upgradient, and reflect better water quality conditions. The plot indicates that variability between stations generally is more significant than time variability at a given location. One exception is at well 24 where a temporary increase in sulfate levels was noted in 1975-76.

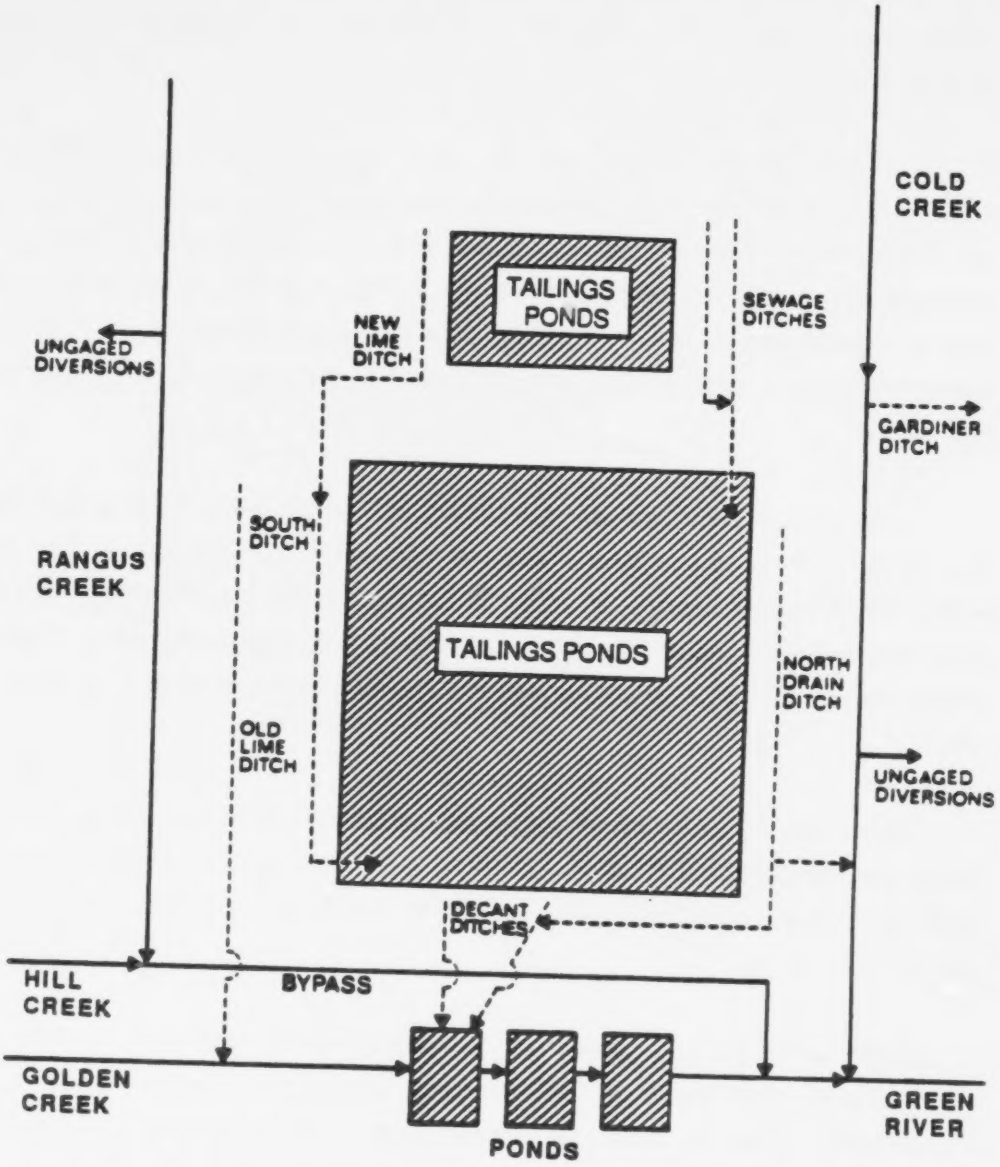
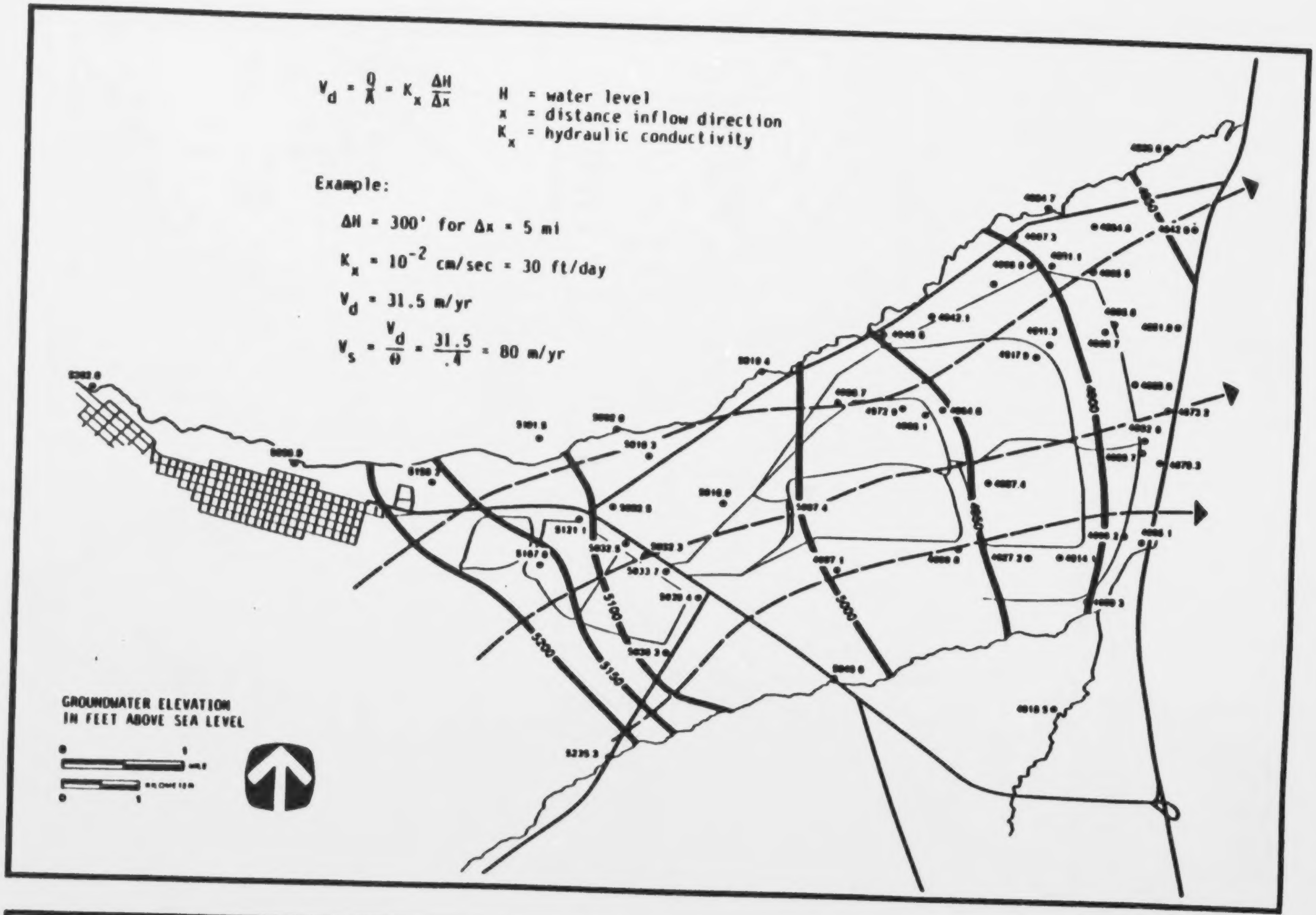

COLD CREEK
TAILINGS PONDS
NEW LIME DITCH
SEWAGE DITCHES
UNGAGED DIVERSIONS
GARDINER DITCH
SOUTH DITCH
RANGUS CREEK
TAILINGS PONDS
NORTH DRAIN DITCH
OLD LIME DITCH
UNGAGED DIVERSIONS
DECANT DITCHES
HILL CREEK
BYPASS
GOLDEN CREEK
GREEN RIVER
PONDS

Figure 15-44. Schematic of Surface Water System



4850
4900
4950
5000
5100
5150
5200
GROUNDWATER ELEVATION
IN FEET ABOVE SEA LEVEL

$V_d = \frac{Q}{A} = K_x \frac{\Delta H}{\Delta x}$

H = water level

x = distance inflow direction

K_x = hydraulic conductivity

Example:

$\Delta H = 300'$ for $\Delta x = 5$ mi

$K_x = 10^{-2}$ cm/sec = 30 ft/day

$V_d = 31.5$ m/yr

$V_s = \frac{V_d}{\theta} = \frac{31.5}{.4} = 80$ m/yr

Figure 15-45. Ground Water Flowlines Based on Measured Water Levels

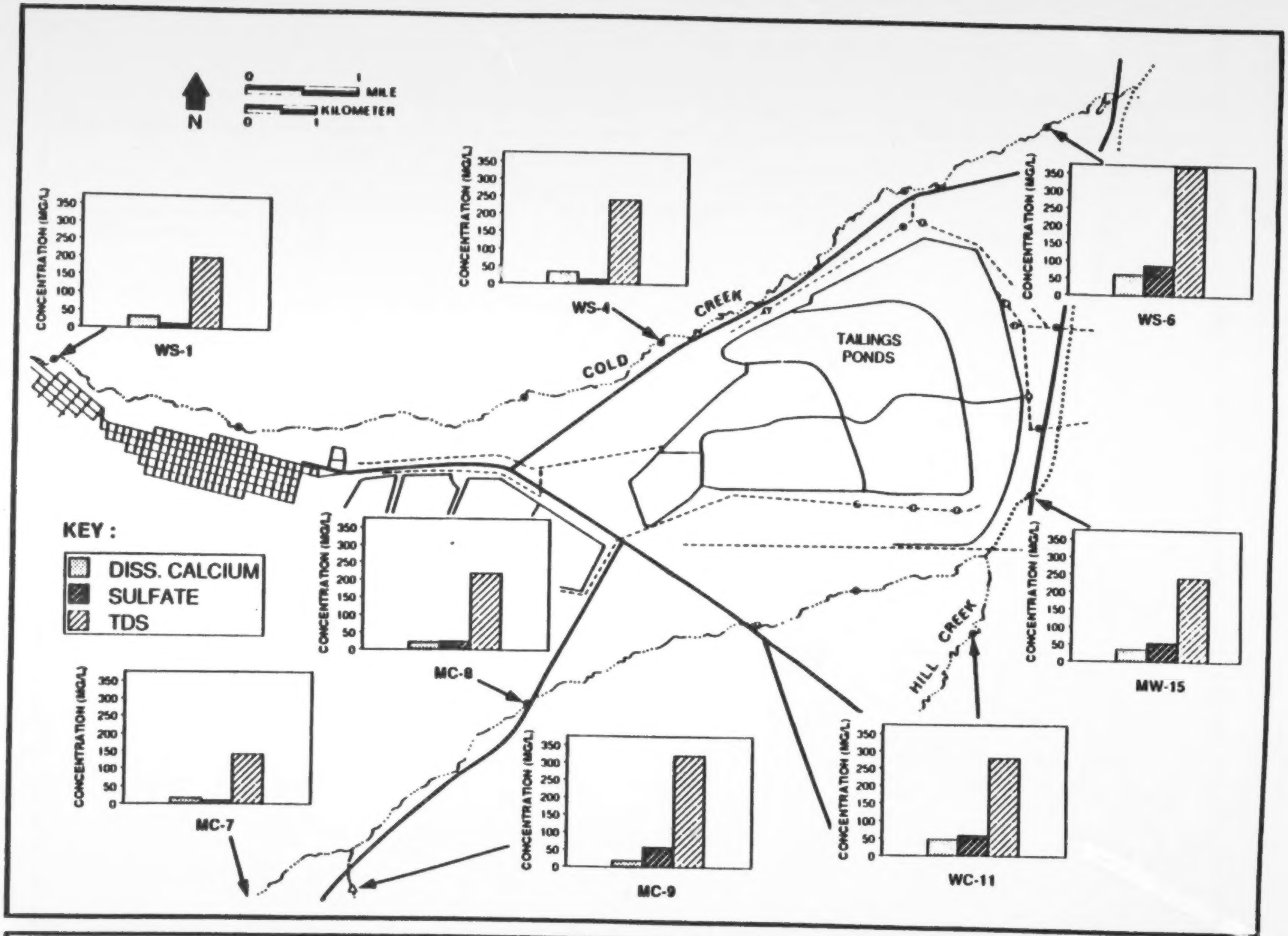

N
0 1 MILE
0 1 KILOMETER
CONCENTRATION (MG/L)
350 300 250 200 150 100 50 0
WS-1
WS-4
WS-6
MW-15
WC-11
MC-9
MC-8
MC-7
COLD CREEK
HILL CREEK
TAILINGS PONDS
KEY :
DISS. CALCIUM
SULFATE
TDS

Figure 15-46. Selected Surface ter Quality Parameters at Key Stations

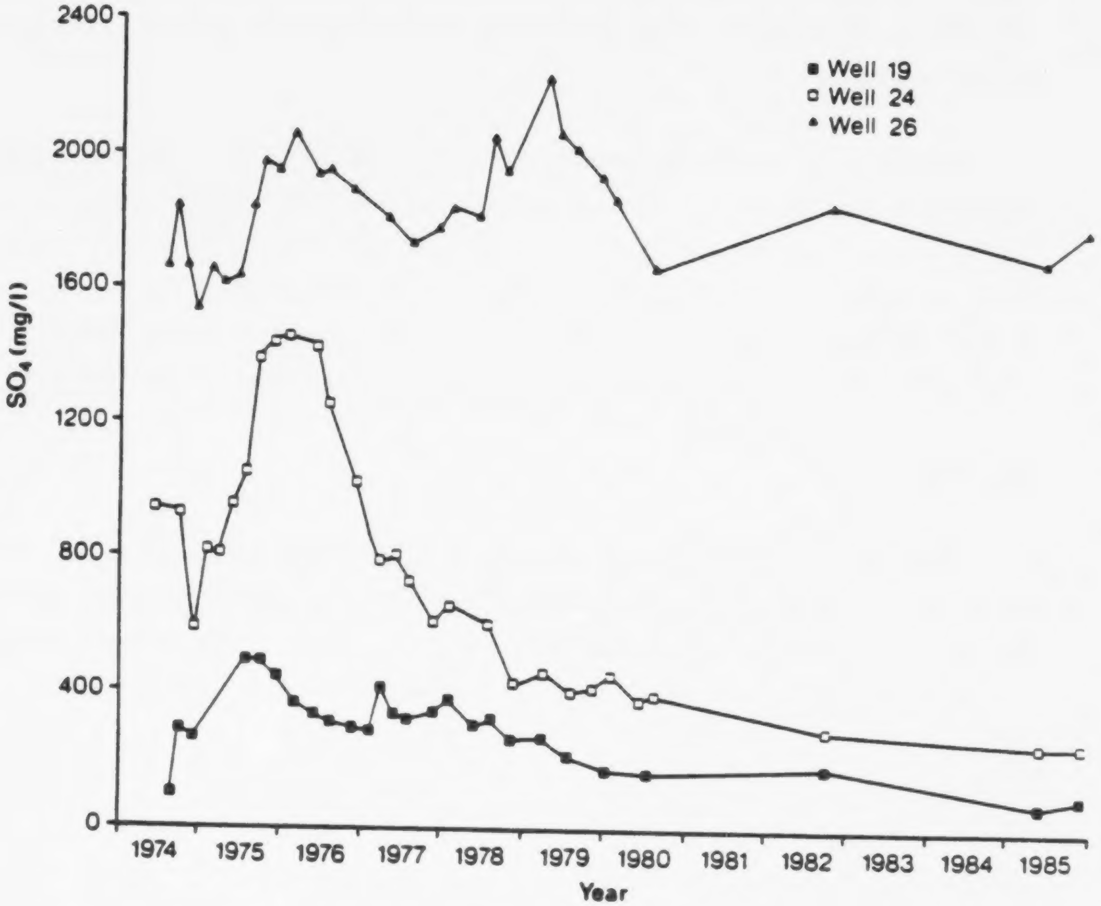


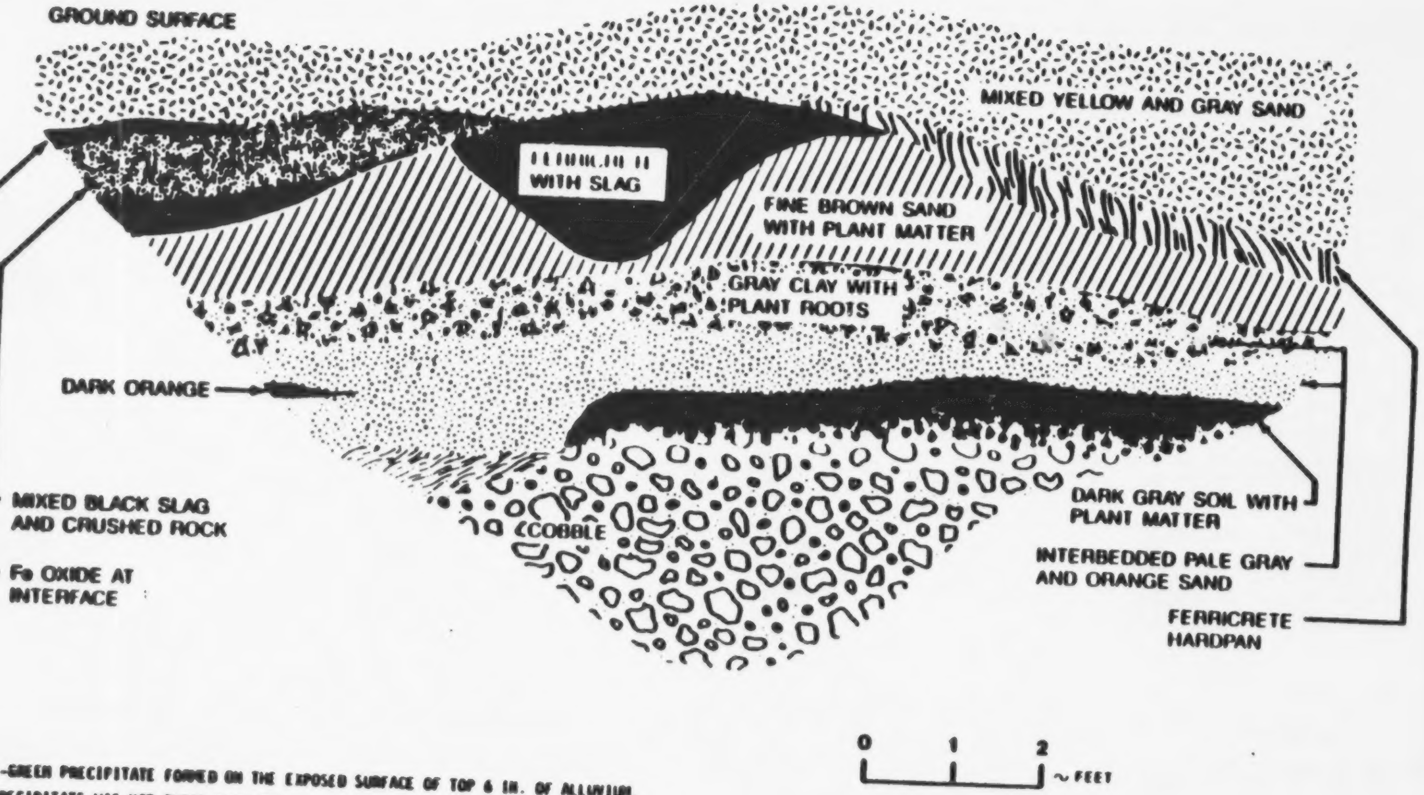
Figure 15-47. Changes in Sulfate Over Time at Selected Wells Located within the Site

To identify leachate and soil interactions beneath a waste site, trenches may be dug. The trench walls are then logged and photographed. Detailed sampling may be done at closely spaced intervals to confirm that reactions such as precipitation have occurred. Figure 15-48 shows a cross-section of a tailings deposit that was developed based on a trench excavated through the tailings into the underlying alluvium. The plot shows the demarcation between wastes and natural alluvium.

Figure 15-49 shows the details of the chemical composition of one borehole through the tailings and into the underlying alluvium. The chemical composition is shown to vary significantly with depth. These types of plots contain a wealth of chemical information that can help to explain the geochemical processes operative in the tailings. Figure 15-49 also shows the marked contrast between the composition of the tailings (in the top 16 feet) and the underlying alluvium.

Summary

The graphical presentations illustrated in this case study are a few of the many techniques available. With the proliferation of graphical packages available on microcomputers, scientists and engineers have a wide range of tools available for data presentation. Some of these tools are summarized in Table 15-19.


GROUND SURFACE
MIXED YELLOW AND GRAY SAND
WITH SLAG
FINE BROWN SAND WITH PLANT MATTER
GRAY CLAY WITH PLANT ROOTS
DARK ORANGE
MIXED BLACK SLAG AND CRUSHED ROCK
Fe OXIDE AT INTERFACE
COBBLE
DARK GRAY SOIL WITH PLANT MATTER
INTERBEDDED PALE GRAY AND ORANGE SAND
FERRICRETE HARDPAN
0
1
2
~ FEET

NOTES: A BLUE-GREEN PRECIPITATE FORMED ON THE EXPOSED SURFACE OF TOP 6 IN. OF ALLUVIUM. THIS PRECIPITATE WAS NOT THERE WHEN TRENCH FIRST DUG.

Figure 15-48. Field Sketch of Tailings Trench T-3

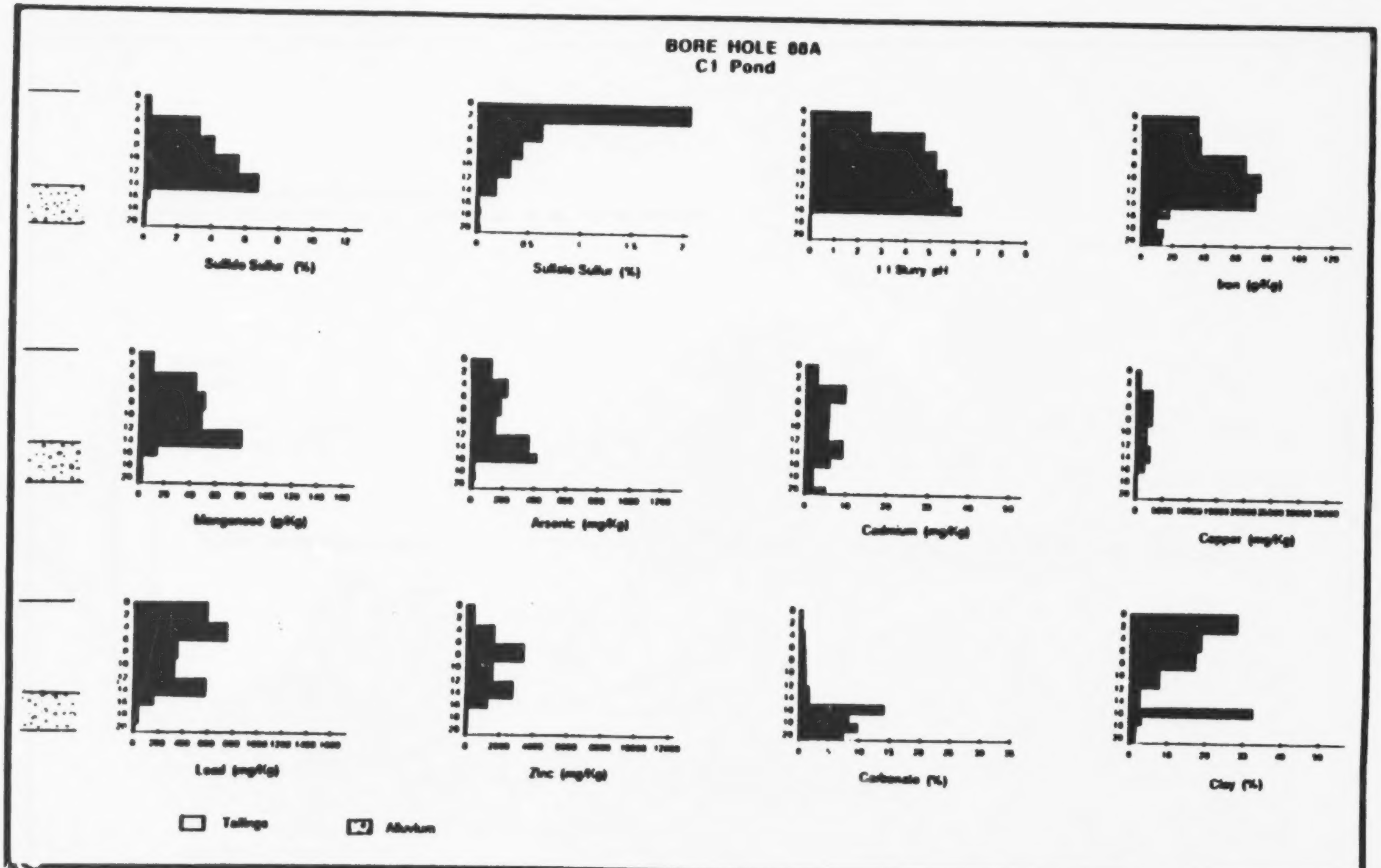


Figure 15-49. Depth vs. Concentration Profiles for Selected Variables for Borehole 88A.

Table 15-19

TYPICAL METHODS FOR GRAPHICALLY PRESENTING DATA COLLECTED DURING FACILITY INVESTIGATIONS

Data	Graphical Presentation Methods
Meteorologic Data	
Wind speed and direction	Wind rose showing speed, direction, and percent of observations for each 10° increment
Air Temperature	Bar chart, by month
Precipitation	Bar chart, by month
Evaporation	Bar chart, by month
Surface Water Data	
Flow rates	• Hydrographs; distance profiles, cumulative frequency distributions, flood frequency plots • Hydrologic network depiction and water budgets
Water quality	• Trilinear diagram • Stiff diagrams • Contour showing vertical concentration or temperature variability in two deep water bodies • Time history plots showing daily/annual variability • Bar charts of major cations/anions or contaminants at multiple locations shown on a single map
Geohydrologic Data	• Geologic map of site and vicinity • Stratigraphic cross-sections of site in direction of and perpendicular to ground water flow • Well logs • Cross sections at waste deposits • Solid phase chemical analyses by depth at borings throughout waste deposits and into alluvium
Ground Water Data	• Water level contours • Flow directions and velocities • Time history of water table at important locations • Stiff diagrams • Trilinear diagrams • Contaminant plumes, showing isopleths
Miscellaneous	• Figures with important site features, including waste sources, storage ponds, disposal areas, buildings, sampling locations, well locations • Operational aspects for special sampling equipment (e.g., lysimeters)

CASE STUDY 26: USE OF QUALITY ASSURANCE/QUALITY CONTROL (QA/QC) AND DATA VALIDATION PROCEDURES

Points Illustrated

- A comprehensive field and laboratory QA/QC program is necessary for assessing the quality of data collected during an RFI.
- Timely validation of laboratory data can uncover problems correctable by reanalysis or by resampling, thus preventing data gaps.

Introduction

A company in the mining and smelting industry sampled domestic wells and surface soils in the vicinity of a tailings pile to monitor possible leaching of metals into the aquifer and possible soil contamination due to wind-blown dust. Because the data would be used to assess corrective measures alternatives and to produce a health and environmental assessment, the company chose to conduct both its sampling and analysis efforts under a formal QA/QC Project Plan and to subject all laboratory data to a rigorous data validation procedure. The overall goal of this effort was to produce data of sufficient quality to withstand the scrutiny of litigation.

Facility Description

At this facility, a tailings pond had received smelter waste for many years. Local water supply wells were potentially at risk due to percolation of water through the pile and possible leaching of heavy metals. Local surface soils in nearby residential areas (e.g., yards, public playgrounds) were also subject to contamination from wind-blown dust originating from the pile during dry windy weather.

Sampling Program

Before sampling began, a set of documents were drafted following U.S. EPA guidelines (U.S. EPA 1978, 1980a, 1980b, 1981, 1982, 1985a, 1985b) that specified in detail sampling sites and parameters to be measured, field and laboratory procedures, analytical laboratory protocols, and all field and laboratory QC checks including frequencies, and corrective actions. The important elements of each document are described below.

Standard Operating Procedures (SOPs)—

This document contained step-by-step procedures for the following items:

- Calibration, operation, and maintenance of all instruments used in the field and field laboratory.
- Equipment decontamination.
- Ground water sampling and soil compositing and sampling.
- Use of field notebooks and document control.
- Sample packaging, shipping, and chain-of-custody.

Field Operations Plan (FOP)—

This document included the following:

- Rationale for choice of sampling locations, sampling frequency, and analytes to be measured
- List of sampling equipment and SOPs to be used for each sampling event.
- List of field QC checks to be used and their frequency for each sampling event.
- Health and safety issues and protective measures for field personnel.
- Sampling schedule.

Laboratory Analytical Protocol (LAP)--

This document included the following:

- Sample size, preservation, and analysis protocol for each analyte.
- List of laboratory QC checks, QC statistics to be calculated and their control limits, and corrective actions for QC checks outside control limits.
- Detailed list of deliverable documents and their formats.
- Procedures for sample custody, independent audits, and general laboratory practices.

QA/QC Project Plan (QAPP)--

This document gathered into one place the overall data quality objectives for the sampling and detailed QC procedures needed to attain those objectives. Included were:

- Quality assurance objectives in terms of precision, accuracy, completeness, comparability, and representativeness.
- Procedures for the screening of existing data.
- Data management, reduction, validation, and reporting.
- Overview of both field and laboratory QC checks and their frequencies, control limits, and corrective actions.
- Data assessment procedures.

Results

Five surface soil samples were taken in high traffic areas of two playgrounds and three residential yards. Five tap water samples were collected at two public drinking fountains at the playgrounds and at the three private residences. The analysis results, as received from the laboratory, are shown in Table 15-20. The data indicated that a soil hot spot existed for cadmium, that elevated lead occurred at all five soil stations, and that all of the domestic wells were contaminated with mercury.

The laboratory data package was subjected to a thorough data validation, as detailed in the QA Project Plan. The following information and QC results were checked by examination of original documents or photocopies of the documents.

Sampling, Sample Shipping, Chain-of-Custody—

Copies of field and field laboratory notebook pages were examined to insure that all SOPs were correctly followed, that there were no notations of anomalous circumstances (such as sample spillage) that may have affected analysis results, and that the samples were correctly preserved, packaged, and shipped. Copies of all chain-of-custody forms, bills-of-lading, and sample analysis request forms were examined to insure that chain-of-custody was not broken and that samples arrived intact at the laboratory.

Laboratory Raw Data—

The QAPP had specified that one of the deliverables from the laboratory was copies of all instrument readouts and laboratory notebook pages. The digestion raw data were checked to insure that no holding time violations had occurred. This is important for mercury because the holding time is only 28 days for aqueous samples.

All raw calibration data were recalculated and tested against instrument-calculated sample results. Recoveries of calibration verification standards and continuing calibration standards were checked to insure that all instruments were

Table 15-20

RESULTS OF ORIGINAL SURFACE SOIL AND TAP WATER ANALYSES

Sample[a]	Cd	Cu	Pb	Hg	Zn
SOIL-1	14	6200	800	NA[b]	1200
SOIL-2	7	2400	400	NA	190
SOIL-3	<20[c]	720	530	NA	70
SOIL-4	19	680	350	NA	350
SOIL-5	1200	1080	460	NA	420
WATER-1	<50	NA	<30	1.5	NA
WATER-2	<50	NA	<30	1.3	NA
WATER-3	<50	NA	<30	1.0	NA
WATER-4	<50	NA	<30	1.4	NA
WATER-5	<50	NA	<30	1.2	NA

---

[a] Soils in units of mg/kg, water in µg/L.

[b] Not analyzed.

[c] Undetected at detection limit shown.

correctly calibrated, were not drifting out of calibration, and were correctly calculating raw analysis results.

Final analysis results were recalculated from raw data using dilution and digestion factors, as summarized in the lab notebooks, and compared to the data summary sheets. No transcription errors were found. However, the cadmium result for SOIL-5 contained a calculation error, and the correct final result was 12 mg/kg instead of the 1200 mg/kg reported.

Laboratory QC Checks--

The QAPP had specified that the laboratory had to analyze pre-digestion duplicates and spikes, U.S. EPA laboratory control samples, and reagent blanks. The laboratory QC results are summarized in Table 15-21 and indicated accuracy and precision well within U.S. EPA guidelines. The mercury preparation blank also indicated that the tap water results were not due to laboratory digestion reagents or procedures.

Field QC Checks--

As specified in the QAPP and FOP, the following field QC samples were included with each of the soils and tap water samplings: bottle blank, field blank, standard reference material (SRM), triplicate, and an interlaboratory split to a "reference" lab. The results are summarized in Table 15-22.

Although no U.S. EPA control limits or corrective actions exist for field-generated QC checks, the results of their analysis can aid in the overall assessment of data quality. The triplicate, SRM, and interlaboratory split analyses indicated good overall analysis and sampling precision and accuracy. The field blanks indicated the possibility of mercury contamination from one of the four possible sources: the pre-cleaned bottles, the preservation reagent, the distilled water used in the field, or an external contamination source such as dust. The high positive mercury result in the water bottle blank eliminated all of these sources except the first because the bottle blanks remained sealed throughout the sampling effort.

Table 15-21

LABORATORY QC RESULTS

Analyte	Duplicate RPD[a] (%) SOIL-2	Duplicate RPD[a] (%) WATER-4	Spike Recovery[b] (%) SOIL-2	Spike Recovery[b] (%) WATER-4	LCS[c] (%)	Soil Preparation Blank[d]	Water Preparation Blank[e]
Cd	18	NC[f]	100	98	101	<50[g]	<50
Cu	5	NA[h]	93	NA	97	<100	NA
Pb	14	NC	110	92	106	<200	<30
Hg	NA	NC	NA	103	NA	NA	<0.20
Zn	7	NA	85	NA	99	<150	NA

---

[a] RPD = relative percent difference = (difference/mean) X100. Control limits = ±35% for solids and ±20% for aqueous samples.

[b] Spike Recovery = $\frac{\text{(spike+sample result) - (sample result)}}{\text{(spike added)}}$ X100. Control limit = 75-125%.

[c] LCS = laboratory control sample. Control limit = 90-110%.

[d] mg/kg.

[e] µg/L.

[f] NC = not calculated due to one or both concentrations below detection limit.

[g] Undetected at detection limit shown.

[h] NA = not analyzed.

Table 15-22

FIELD QC RESULTS

	Triplicate CV[a] (%)		SRM Recovery[b] (%)		Interlab. RPD[e] (%)		Field Blanks[f]		Bottle Blanks[g]	
Analyte	SOIL-1	WATER-1	BCSS-1[c]	U.S.EPA[d]	SOIL-1	WATER-1	SOIL	WATER	SOIL	WA
Cd	22	NC[h]	83	105	-12	NC	<50[i]	<50	<0.5	<0
Cu	3	NA[j]	94	NA	0	NA	<100	NA	<1	
Pb	7	NC	97	101	14	NC	<200	<200	<0.5	<0
Hg	NA	18	NA	103	NA	19	NA	1.1	NA	0
Zn	1	NA	110	NA	24	NA	<150	NA	<1	

---

[a] Cu = coefficient of variation = (mean/standard deviation) X100.

[b] Recovery = (certified value/result) X100.

[c] National Research Council of Canada marine sediment.

[d] S. EPA Trace Metals I, Concentration #1.

[e] RPD = relative percent difference = [(analytical lab result - ref. lab. result)/mean] X100.

[f] Distilled water. Units = µg/L.

[g] Empty containers rinsed with digestion reagents at lab. Units = total µg.

[h] NC = not calculated due to at least one sample result below detection limits.

[i] Undetected at detection limit shown.

[j] NA = not analyzed.

The laboratory was immediately called, and upon personal inspection, the laboratory manager discussed the remnants of a broken thermometer bulb in the plastic tub used to acid-soak the bottles. An unused bottle from the same lot and still at the laboratory as well as two bottles washed in previous lots were analyzed. The bottles previously washed contained no mercury (above detection limits), and the bottle from the same lot as used in the sampling effort contained 0.75 μg. The water mercury data were rejected, and a second sampling effort using new bottles was conducted. All of the new samples contained no mercury (above detection limits).

Discussion

This case study demonstrates the need for the establishment of a formal QA/QC program that not only specifies field QC protocols but also incorporates thorough data package validation. In this instance, a potential hot spot was found to be only a calculation error, and mercury contamination of domestic well water was found to be only an artifact of using contaminated sample containers. In the latter case, timely QA/QC review allowed for a speedy resampling effort which could be done at this site. In many situations, resampling is not possible, and thus QA is even more important.

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CASE STUDY 27: CORRECTIVE ACTION AND THE IMPLEMENTATION OF INTERIM MEASURES

Points Illustrated

- Interim corrective measures may be necessary to protect human health or the environment.
- The evaluation of the need for definitive corrective measures.

Introduction

The development and implementation of a comprehensive corrective action plan can be a time-consuming process. Between the time of the identification of a contaminant release and the completion of corrective actions, existing conditions or contaminant migration can endanger human health or the environment. Under these conditions interim measures are required. The case study presented below illustrates the implementation of interim measures to reduce contaminant migration and to remove the imminent threat to the nearby population from exposure to contaminants in drinking water, and also illustrates the decision-making process as to whether definitive corrective measures may be necessary.

Facility Description

The facility in this case study is an underground tank farm located at a pharmaceutical manufacturing plant. The tank farm encompasses an area approximately 140 feet by 260 feet and contains 30 tanks ranging in size from 12,000 to 20,000 gallons. The tanks are used to store both wastes and raw materials for the various batch manufacturing processes performed at the plant. Typical wastes include carbon tetrachloride, acetonitrile and chloroform. At the time of the release, the tank farm had no cap to prevent the infiltration of rainfall or runoff. It also did not have berms to provide containment for surface spills. No leak detection or leachate collection systems were present.

Geological and Hydrological Setting

The site is underlain by silty soil overlying limestone. The weathered limestone beneath the site is very permeable (up to 210 ft/day) due to the solution of rock along joints and bedding planes in the limestone. Depth to the limestone varies from 3 to 80 feet beneath the tanks and from 15 to 190 feet downgradient of the site.

The ground water system beneath the site consists of two aquifers. The upper one, an unconfined limestone aquifer, is located about 300 feet below the surface. The deep aquifer is an artesian aquifer in another limestone formation located about 1200 feet below the land surface. Ground-water flow in the upper aquifer is controlled by both the regional flow system and local channelized flow through solution conduits. The upper aquifer discharges to a canal 3 miles north of the site. Figure 15-50 shows the ground water elevation contours in the vicinity of the site. Regional average ground water flow velocity was estimated at 4 ft/day, but ground water velocities on the order of 50 ft/day have been measured in some channelized areas. Channelized flow is also responsible for local deviations in flow direction.

Release Characterization

A contaminant release from the tank farm was discovered when one of the tanks used for waste storage was found to be empty. The waste stored in the tank was predominately carbon tetrachloride (CCl_4) (a carcinogen with a risk specific dose (RSD) of 0.001 μg/l), with some acetonitrile (a systemic toxicant for which no health criteria presently exists) and chloroform (a systemic toxicant for which the reference dose (RfD) is 0.4 mg/l). Approximately 15,000 gallons of waste liquids had been routed to the tank before the leak was discovered. Excavation of the tank revealed ruptures in at least three locations. Initial ground-water monitoring after the tank rupture was discovered identified CCl_4 in a well located 2500 feet downgradient of the site, at concentrations above the Risk Specific Dose for CCl_4 of 0.001 μg/l.

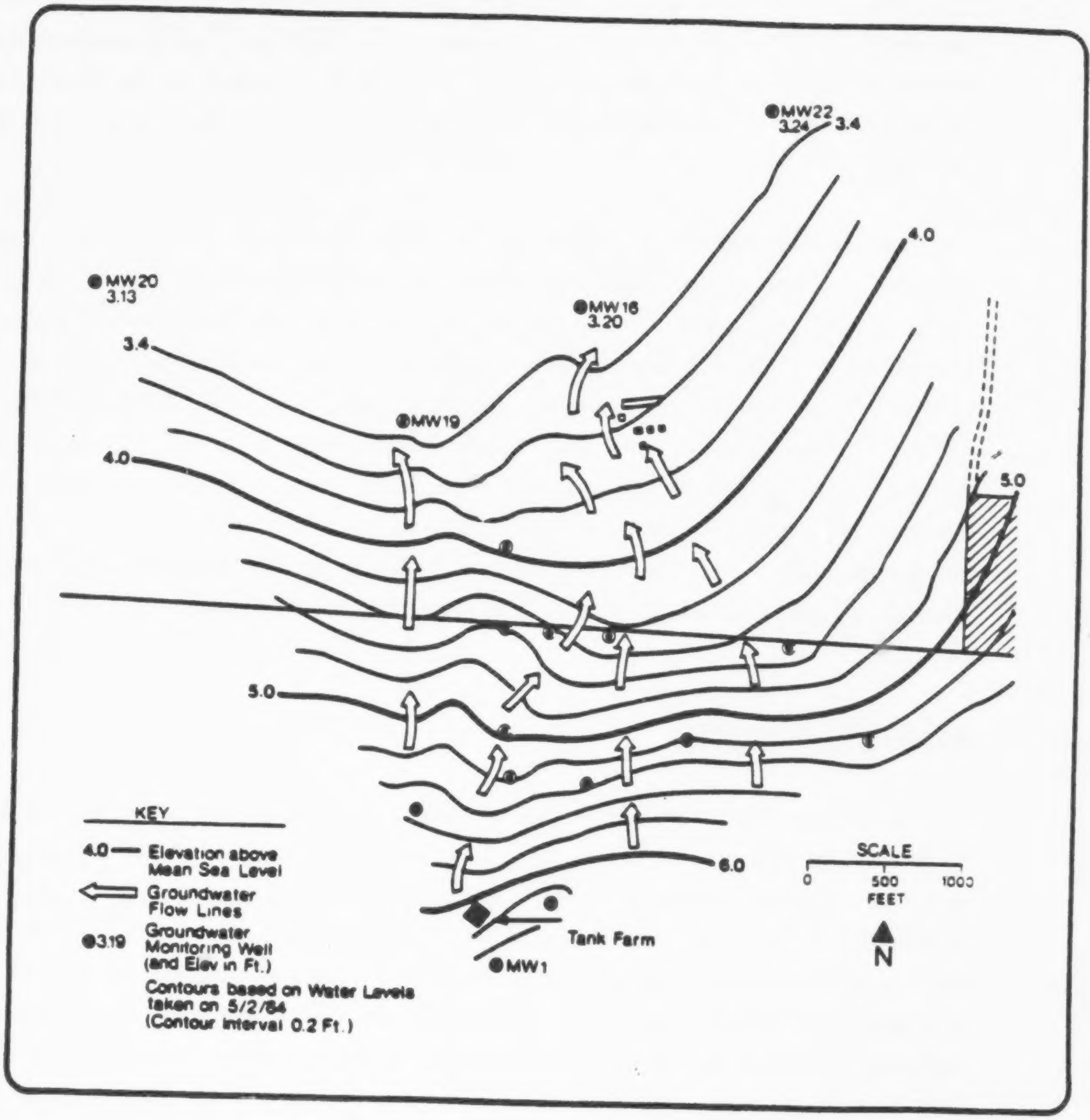
MW22
3.24
3.4
4.0
MW20
3.13
MW16
3.20
3.4
MW19
4.0
5.0
5.0
6.0
KEY
4.0 Elevation above Mean Sea Level
Groundwater Flow Lines
3.19 Groundwater Monitoring Well (and Elev in Ft.)
Contours based on Water Levels taken on 5/2/84 (Contour interval 0.2 Ft.)
Tank Farm
MW1
SCALE
0
500
1000
FEET
N

Figure 15-50. Ground water level elevations and flow directions in upper limestone aquifer.

Contaminants from the leaking tank were found to have dispersed laterally within a two foot thick sand bed which underlies the tanks. The contaminated area was approximately 5600 ft^2. High levels of CCl_4 were found throughout the sand layer. Concentrations of CCl_4 in the natural soil ranged between undetected and 2200 mg/L. Observed concentrations were well above the RSD for CCl_4. Concentrations generally decreased with depth due to adsorption onto the clay particles in the soil. Carbon terachloride apparently moved downward with little lateral dispersion until reaching the soil-limestone interface. Upon reaching the unsaturated limestone, the contaminants then appeared to have rapidly dispersed over an area of about 12 acres before entering the aquifer.

Interim Corrective Measures

Immediate action to contain the release in the aquifer was taken. This involved pumping the well where CCl_4 had been found continuously at its full capacity of 450 gpm.

All drinking water in the vicinity of the release was obtained from wells installed in either the shallow or artesian aquifers. Immediately after the detection of the release, all domestic and industrial wells located north of the facility were tested for CCl_4 contamination. Test results showed contamination of several shallow water supply wells. Based on this information and the inferred ground water flow direction to the north-northeast, wells serving two small communities and a nearby motel were closed. The facility operator hired all trailable water tanks available and supplied water for immediate needs until a temporary water supply could be implemented. Water from an unaffected artesian well was then used to supply water to these communities.

The design and operation of the tank farm was altered in an attempt to avoid similar problems in the future. A fiber-reinforced concrete cap was installed over the tank farm to prevent the infiltration of rainfall and runoff, thus minimizing further contaminant migration in the soil. The ruptures were repaired, and a tank monitoring system was also developed and implemented at the site.

Definitive Corrective Measures: Saturated and Unsaturated Zones

A comparison of CCl_4 concentrations within the ground water to the RSD for CCl_4 (0.001μg/l) indicated that definitive corrective measures may be necessary. Due to the high mobility of CCl_4 within the unsaturated zone, and the potential for continued inter-media transfer from this zone to the ground water, definitive corrective measures for both the saturated (ground water) and unsaturated zones should be evaluated in a corrective measures study (CMS).

Case Discussion

The development and implementation of corrective action at a site may take a substantial length of time. Depending on the nature of the release and the site involved, interim measures, such as alternative water supplies, were required to minimize the effects on human health and the environment. Comparison of constituent concentrations with health and environmental criteria indicated that definitive corrective measures may be necessary and that a corrective measures study (CMS) should be initiated.

CASE STUDY 28: METHODOLOGY FOR CONSTRUCTION OF VERTICAL FLOW NETS

Point Illustrated

- Construction of a vertical ground-water flow net can be a valuable tool for evaluating ground-water (and contaminant) pathways and for determining additional actions that may be necessary to accurately delineate the ground-water flow regime at a facility.

Introduction

Constructing a vertical flow net at a facility provides a systematic process for analyzing the accuracy of ground-water elevation and flow data, and can therefore foster a better understanding of the ground-water flow regime at the site.

Facility Description and History

The site contains a large chemical manufacturing facility of approximatley 300 acres located beside a major river in the northeastern United States. The site has been used for chemical manufacturing by different companies since 1904 and has a long history of on-site waste management. Several solid waste management units have been identified at the facility. This is the same facility as discussed in Case Studies 3, 4, 18, and 20.

Geologic and Hydrologic Setting: At depths of 150 to 200 feet the site is underlain by bedrock identified as arkosic sandstone. Above this bedrock are glacial deposits consisting of a thick bed of hard till, overlain by lacustrine sediments and deltaic and outwash deposits. Discontinuous lenses of till were identified within the deltaic deposits. A trough cut into the thick-bedded and trending approximately southeast to northwest has been identified. See Figure 1.

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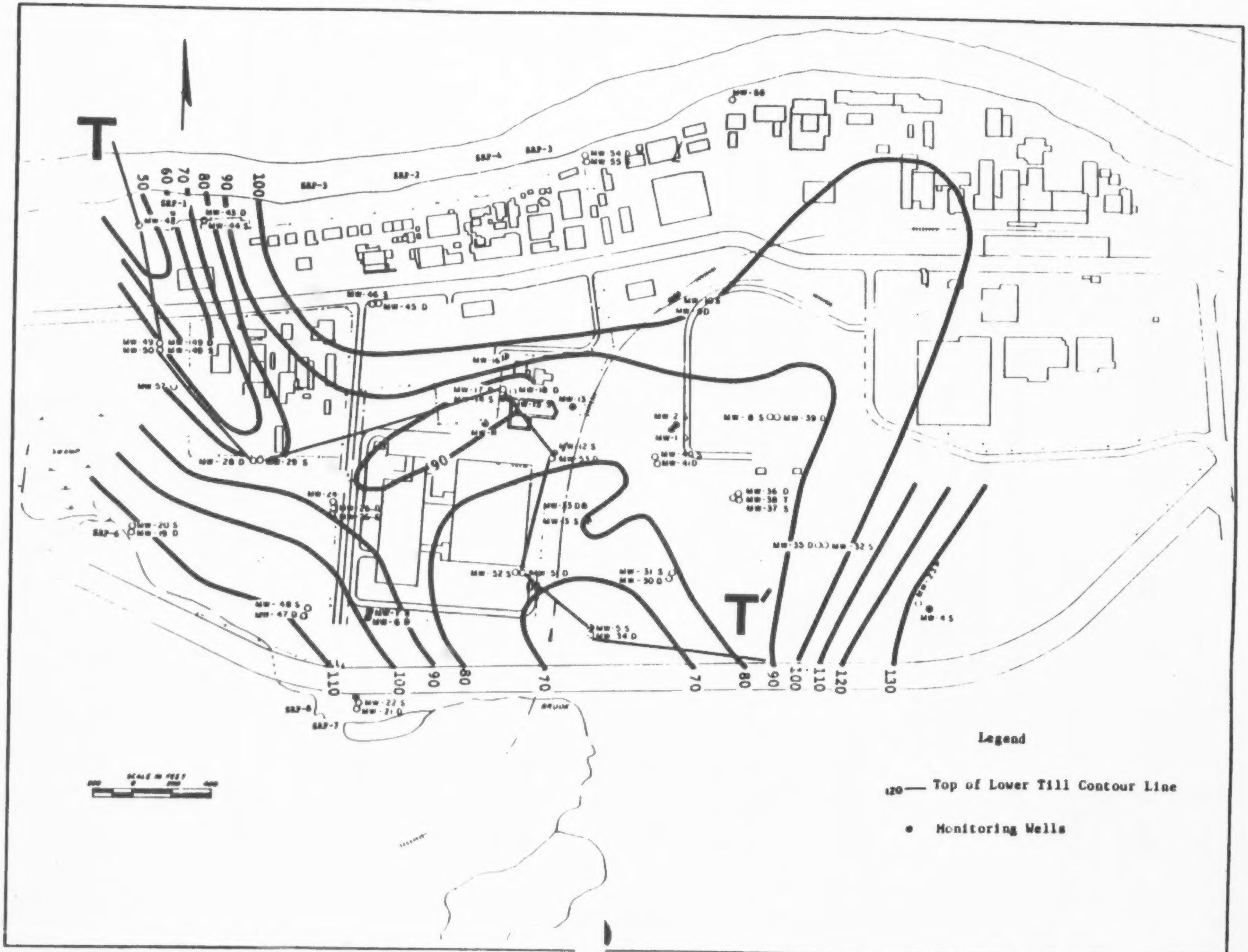

T
T′
50
60
70
80
90
100
110
120
130
MW-42
MW-43 D
MW-44 S
MW-45 D
MW-46 S
MW-49
MW-50
MW-51
MW-28 D
MW-29 S
MW-20 S
MW-19 D
MW-22 S
MW-21 D
MW-48 S
MW-47 D
MW-34 D
MW-35 S
MW-86
MW-10 S
MW-9 D
MW-12 S
MW-53 D
MW-33 D
MW-31 S
MW-30 D
MW-32 S
MW-35 D
MW-36 D
MW-38 T
MW-37 S
MW-39 D
MW-8 S
MW-40 S
MW-41 D
MW-5 S
MW-34 D
MW-4 S
MW-13
MW-17
MW-18 D
MW-16
SRP-1
SRP-2
SRP-3
SRP-4
SRP-5
SRP-6
SRP-7
SRP-8
SWAMP
BROOK
SCALE IN FEET
200 0 200 400
Legend
120 — Top of Lower Till Contour Line
● Monitoring Wells

Figure 1: Top of Lowest Till Contour Map and Location of Vertical Flow Net

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The river beside the facility flows westward and discharges into the main stem of a larger river approximately 4 miles west of the facility. A small tributary (Brook) borders the facility to the southwest and west. Swamp-like areas are present near the tributary. It is suspected that the arkosic sandstone outcrops in the river adjacent to the facility. Whether this visible rock is a large glacial erratic or an outcrop of the arkosic sandstone bedrock is an issue identified during previous investigations and may be important in characterizing the ground-water flow regime at the facility.

Program Design

The site was investigated in two phases. Phase I (1981-1984) included the installation and monitoring of wells MW-1 through MW-12, while Phase II (1984-1985) consisted of 34 soil borings, installation of wells NW-13 through MW-57, and monitoring and sampling of all wells. This two-phased approach allowed for the use of the initial monitoring well data and soil boring data to determine the placement of the Phase II monitoring wells. Further discussion of this two-phased approach is provided in Case Studies 4 and 19.

Data Analysis

Evaluation of the data was conducted based on information provided by the owner/operator, including the water-level elevation data presented in Table 1. Well locations and water-level elevations in the wells were mapped and compared to elevations of the midpoint of the well screens, to show relative hydraulic head differences from well to well. Vertical gradients are a reflection of different head values at different elevations. For each well, the head can be determined at the elevation of the midpoint of the well screen by measuring the water-level elevation in the well. Different head values corresponding to different screen elevations are used to evaluate vertical gradients. During the plotting of this map, anomalous data were identified and marked for further investigation.

The geology of the site and the depositional processes forming the aquifer were studied to determine what sorts of hydrogeologic phenomena might be expected. Glacial outwash deposits exhibit trends in sediment size and sorting. Sediment size

Table 1

Ground-Water Elevation Summary Table Phase II

Well Number	Ground Elevation (ft.)	Well Depth (ft.)	Midpoint of Well Screen Elevation[1]	Screen Length (ft)	Water Level Elevation 9/1/82
MW-1	162.80	76.50		3	
MW-2	162.50	22.50		3	
MW-3	174.20	31.00	145.7	3	150.54
MW-4	201.90	54.00	150.4	3	156.85
MW-5	186.30	47.50	141.3	3	149.95
MW-6	144.30	39.50	107.3	3	135.78
MW-7	144.60	19.50	127.6	3	135.94
MW-8	155.10	24.00	133.6	3	149.04
MW-9	160.50	61.00	135.0	3	141.53
MW-10	160.40	30.00	132.9	3	144.62
MW-11	154.70	27.00	130.2	3	140.57
MW-12	159.50	26.50	135.5	3	141.05
MW-13	162.20	29.00	139.2	10	141.22
MW-14	162.10	29.00	139.1	10	140.66
MW-15	162.00	29.00	139.1	10	140.67
MW-16	162.00	29.00	135.5	3	140.87
MW-17	162.00	71.00	104.5	25	140.52
MW-18	161.90	72.00	103.4	25	140.53
MW-19	137.10	24.00	116.6	5	127.83
MW-20	137.20	17.00	123.7	5	127.82
MW-21	141.40	26.50	118.4	5	135.39
MW-22	141.60	15.10	13.0	5	135.35
MW-23	204.30	225.50	-10.2	20	184.98
MW-24	143.90	70.00	76.4	5	136.47
MW-25	143.80	39.00	107.3	5	130.20
MW-26	143.80	24.00	123.2	5	130.17
MW-27*					
MW-28	142.70	46.00	100.2	5	127.86
MW-29	142.80	23.00	123.3	5	127.88
MW-30	172.00	85.50	90.0	5	152.70
MW-31	172.20	24.85	150.8	5	151.68
MW-32	203.10	61.00	145.6	5	154.78
MW-33	174.20	94.00	83.7	5	150.49

*Not installed.

[1] Assume screens are installed one foot above the bottom of the well.

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Table 1 (continued)

Well Number	Ground Elevation (ft.)	Well Depth (ft.)	Midpoint of Well Screen Elevation[1]	Screen Length (ft)	Water Level Elevation 9/1/82
MW-34	186.20	75.80	113.9	5	149.72
MW-35	203.20	106.25	100.4	5	144.31
MW-36	189.40	101.20	91.7	5	143.22
MW-37	189.50	48.00	145.0	5	150.51
MW-38	189.30	135.30	57.5	5	145.04
MW-39	154.90	68.00	90.5	5	142.45
MW-40	173.80	47.50	129.8	5	146.59
MW-41	173.70	75.30	101.9	5	141.95
MW-42	134.20	64.00	73.7	5	117.62
MW-43	139.50	32.10	80.9	5	117.24
MW-44	139.50	28.00	115.0	5	119.62
MW-45	144.32	35.00	112.8	5	128.97
MW-46	144.15	25.00	122.6	5	126.48
MW-47	141.50	34.00	111.0	5	131.91
MW-48	141.60	17.00	128.1	5	131.74
MW-49	143.00	72.20	74.3	5	123.22
MW-50	143.00	30.20	116.3	5	123.85
MW-51	157.00	70.30	90.2	5	149.58
MW-52	157.00	34.00	126.5	5	139.48
MW-53	159.30	77.90	84.9	5	141.09
MW-54	145.80	52.00	97.3	5	120.18
MW-55	145.90	35.00	114.4	5	121.63
MW-56	133.60	20.30	116.8	5	119.84
MW-57	141.90				
Steam Reference Points					
SRP-1				114.41	
SRP-2				114.92	
SRP-3				116.05	
SRP-4				115.86	
SRP-5				NA	
SRP-6				128.81	
SRP-7				137.28	
SRP-8				134.11	

*Not installed.

[1] Assume screens are installed one foot above the bottom of the well.

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decreases and sorting increases trending from the marginal to the distal portions of the deltaic/lacustrine deposits.[1] It is expected that this tendency will be reflected in hydraulic conductivities throughout the outwash deposits at the facility. There is some suggestion of such a trend in the head data from the site.

The map of head values and screen midpoint elevations were evaluated considering both the possible hydrogeologic phenomena expected for the geology of the area and the depositional processes creating the aquifer. Several working hypotheses were developed to explain the apparent ground-water flow patterns and the identified vertical gradients.

- Hypothesis 1: Vertical gradients can be explained by classifying areas where the vertical gradients were reflective of discharge and recharge areas. See Figure 2.

- Hypothesis 2: The top surface of the till forms a trough with a saddle. See Figure 1. The vertical gradients showing higher head with depth reflect the movement of water as it flows upward over the saddle.

- Hypothesis 3: The vertical gradient may correlate with locations of buildings and parking lots at the site. Recharge occurs primarily where the ground is not paved. The downward gradient near the river may be caused by runoff flowing downhill and recharging the ground water at the edge of the pavement.

- Hypothesis 4: Most of the ground-water flow is horizontal. The vertical gradients reflect phenomena whose scale is smaller than the resolution of available data, and an accurate interpretation cannot be made. Geologic systems exhibit heterogeneity on different scales, causing fluctuations in head on different scales. The small-scale fluctuations detected at the site are due to undefined causes and may represent:

    1. details of stratigraphy (such as till beds in parts of the outwash deposit),
    2. artificial recharge and discharge (such as leaky sewer pipes), or
    3. errors in the data.

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[1] Mary P. Anderson, "Geologic Facies Models: What Can They Tell Us About Heterogeneity," presented to the American Geophysical Union, Baltimore, May 18, 1987.

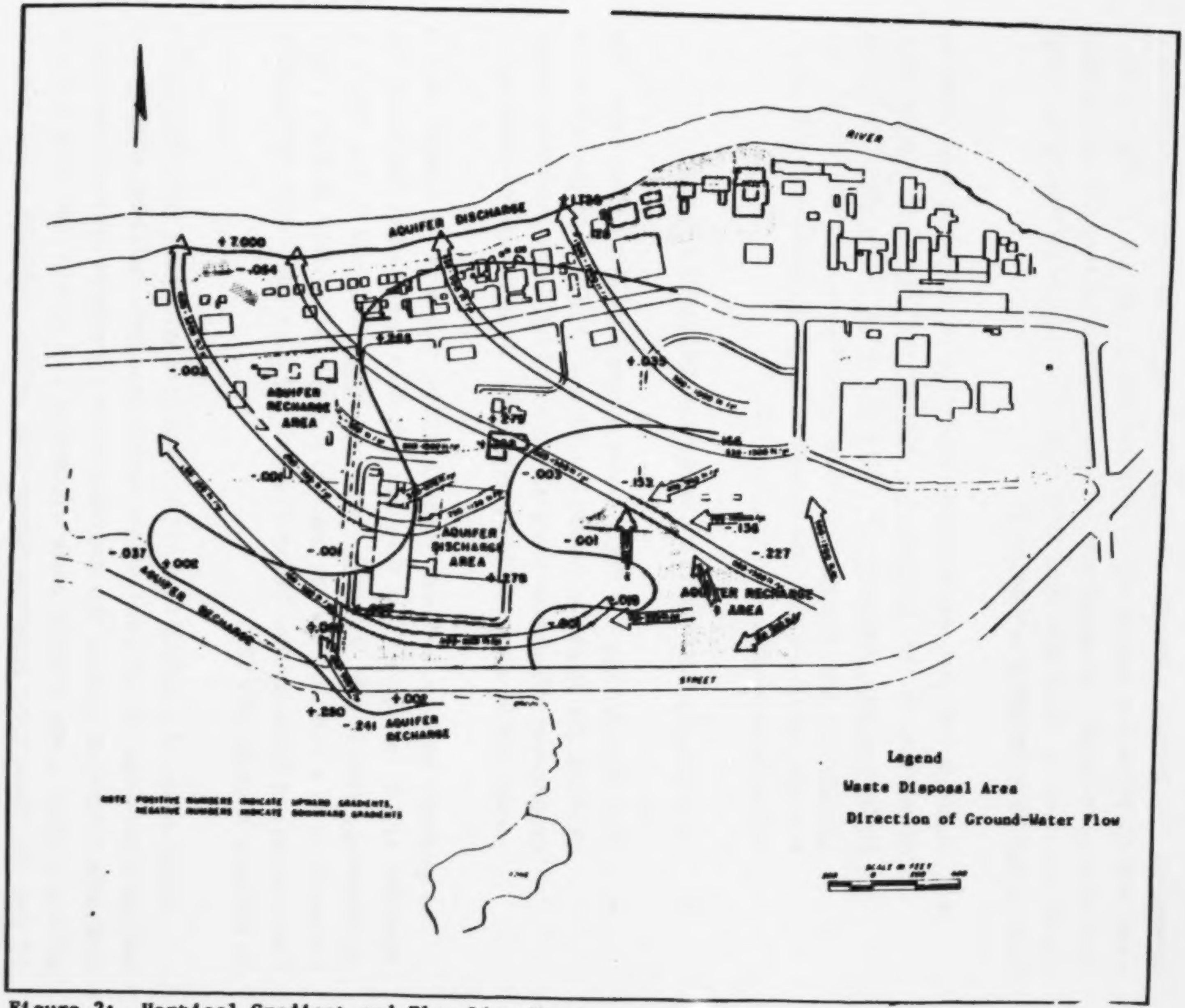
RIVER
AQUIFER DISCHARGE
+1.130
+7.000
-.084
+.288
-.002
AQUIFER RECHARGE AREA
+.035
+.270
.164
-.003
-.153
-.136
-.227
-.001
AQUIFER DISCHARGE AREA
+.278
AQUIFER RECHARGE AREA
.018
-.001
-.037
+.002
AQUIFER RECHARGE
+.040
+.002
+.280
-.241
AQUIFER RECHARGE
STREET
NOTE POSITIVE NUMBERS INDICATE UPWARD GRADIENTS,
NEGATIVE NUMBERS INDICATE DOWNWARD GRADIENTS
Legend
Waste Disposal Area
Direction of Ground-Water Flow
SCALE IN FEET
200
0
200
400

Figure 2: Vertical Gradient and Flow Line Map

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To characterize flow at the site and to support the design of corrective measures (if needed), a working (conceptual) model of flow at the site should be developed. This model, in this case a vertical flow net, can be used to identify data gaps and to prioritize gathering of the necessary additional information. Considering the hypotheses developed, an area for characterizing the vertical flow regime was selected. Determination of this area, where a geologic cross section and flow net will be constructed, was based on:

- Assumptions and requirements necessary to construct flow nets, as identified in the Criteria for Identifying Areas of Vulnerable Hydrogeolgoy, Appendix B: Ground-Water Flow Net/Flow Line Construction and Analysis (Vulnerable Hydrogeology, Appendix B). For example, ground-water flow should be roughly parallel to the direction of the cross-section and vertical flow net.

- Flow being representative of the hydrogeology of the facility.

- Flow representing the major paths of ground-water movement. For example, the aquifer is shaped like a trough and a major portion of the ground-water flow occurs in the middle of this trough; therefore, a cross-section and flow net should be constructed along the axis of the trough.

A geologic cross-section was constructed for the area of interest and is identified as T-T' in Figure 1. A flow net was then constructed following the methodology described in Vulnerable Hydrogeology, Appendix B; see Figure 3. Construction of a vertical flow net requires a graphical solution of Darcy's Law. Data that do not fit the solution become evident in Figure 3 as shown, for example, by the head value for MW 52.

Construction of a vertical flow net allowed for a systematic evaluation of the various hypotheses. Hypothesis 1, where vertical gradients are labled recharge and discharge, is rejected because the magnitude of the graidents varies by two orders of magnitude in a very irregular pattern (compare well clusters MW 14-18 and MW 12 and 53); there is no apparent reason that natural recharge would vary so irregularly. Hypothesis 2 seemed reasonable initially, but after closer inspection, is rejected because upward gradients are not consistently found near the saddle.

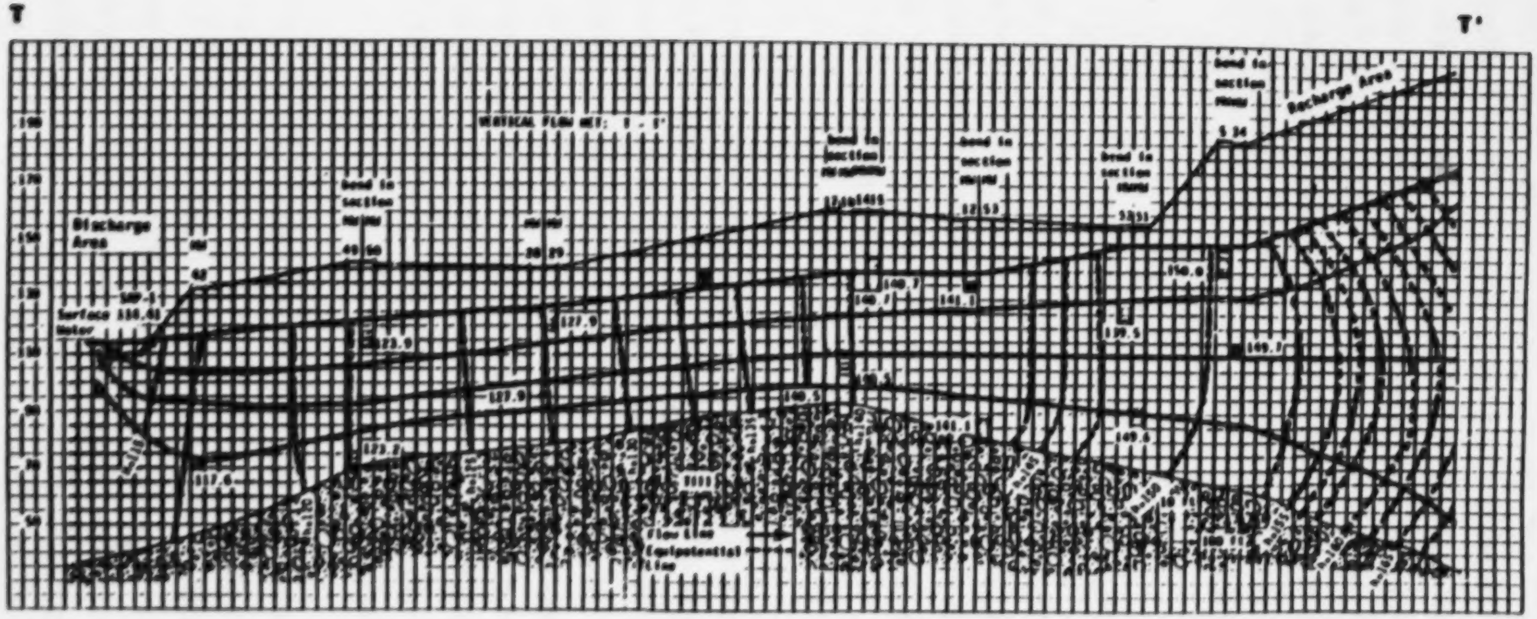
T
T'
VERTICAL FLOW NET: T - T'
Discharge Area
Recharge Area
Surface Water
bend in section
Flow line
Equipotential line
117.6
123.9
127.9
140.5
141.1
150.0
149.7

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Figure 3: Vertical Flow Net T-T'

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Hypothesis 3 is feasible and deserves further study. Aerial photographs were examined to identify paved and unpaved areas, but the available ground-water data are insufficient for detailed correlation to these distinct areas. Additional data are needed to construct a more-detailed flow net to further evaluate this hypothesis. Hypothesis 4, which asserts that most of the flow is horizontal, addresses the area of the site where the major portion of ground-water flow occurs. Although it relies on undefined causes to explain fluctuations, it reflects the most logical explanation of the data.

Results

During construction of the flow net and testing of the hypotheses several issues were identified. One of the most important gaps in the study to date is how localized flow at the site fits into the regional ground-water flow regime. Regional flow issues would need to be resolved prior to determining the extent and type of corrective measures, if necessary. The following regional flow issues were identified:

- Geologic information beyond the facility property boundary is necessary to explain the suspected bedrock in the middle of the River directly beside the site to characterize the regional ground-water flow (i.e., to determine the possibility for contamination of regional ground water). The difference in elevation of the top of the bedrock in the River and the top of the bedrock throughout the facility is approximately 120 feet. How can this be explained? Is the bedrock surface irregular or is this rock a glacially-transported boulder exposed in the river? How does this affect regional ground-water flow?

- Data consistently show a downward gradient (i.e., recharge conditions) near the river. This is difficult to explain because rivers in this region are not expectd to be losing streams (Heath, 1984). The expected flow direction near a ground-water discharge area, in this case a gaining stream, is upward. Data points showing downward flow near the river are not included in flow net T-T'. (Further investigation of vertical gradients near the River is recommended). If this downward gradient near the river is confirmed, near-water-table contamination could move downward and contaminate deeper ground-water. If deeper, regional contamination must be addressed, and corrective measures may be significantly more difficult and extensive.

Other issues deal with localized flow patterns that may affect design of corrective measures. Resolution of these issues will probably not change the overall scope of corrective measures, but would need to be considered in the detailed design.

These localized flow pattern issues are as follows:

- The hydraulic head in the Brook is higher than the head in the closest wells in the aquifer, but the water slopes toward the stream. This is inconsistent. If ground water from the site is not discharging into this stream, fewer interceptor wells may be needed.
- Anisotropy must be taken into account in determing the region of flow captured by interceptor wells, drains, etc.
- Till identified as lenses in outwash deposits may actually be continuous with upgradient till, causing the aquifer to flow under confined conditions. Are the till beds isolated lenses or are they continuous? If the till beds in the outwash aquifer are continuous and isolate adjacent zones within the aquifer, they will have the potential of blocking flow to interceptor wells that may be included in the corrective measures plan.
- Vertical gradients of 0.25 and 0.002 in the same geologic unit are presented. Are these gradients accurate and how can they be explained? There could be artificial discharge (pumping) or recharge (possibly from a leaking sewer) near the wells showing a high vertical gradient. The areas labeled discharge areas show no signs of surface water or other surficial evidence of discharge. Artificial recharge and discharge may create areas of relatively constant head, such as where ground water contacts leaky sewers; these areas could limit the growth of cones of influence of any interceptor wells or drains. Also, any contaminated water that may be discharging from pipes should be identified and corrected.

Case Discussion

Further investigation is necessary to resolve the above issues. Regional flow issues should be resolved first. This information would be used to better understand localized flow patterns which would affect the design of corrective measures. The following options for further investigation are suggested:

1. Study the regional geology and hydrogeology. Techniques that could be employed by using existing data include review of geologic maps, analysis of well logs, and interpretation of existing surface geophysical data (e.g., gravity and magnetic surveys). Measurement of water level elevations in wells outside the site would also be useful.

2. Conduct a detailed study of the depositional environment of the glacial deposits on the site. This should provide a better understanding of flow patterns.

3. Collect a full-year series of head data at existing wells to differentiate transient from steady-state (e.g., artificial from natural) effects in the measured heads.

4. Conduct multiple-well pumping tests to determine the degree of connectivity of geologic formations using wells at different depths and locations. [Note: This should be done with careful attention to details of well construction so that it is understood exactly what is being measured.]

5. Collect detailed chemical data (including major ions and contaminants) at the existing wells and interpret them to aid in characterizing the flow regime.

6. Drill one or more wells into the bedrock near the river to determine the vertical component of ground-water flow at this location.

Options 1 through 5 above are recommended prior to drilling additional wells in the outwash deposits, unless more wells are needed to delineate the release.

Further single-well hydraulic conductivity tests in the glacial deposits are not recommended at this time. The large-scale flow in the outwash aquifer should be determined by the location and relative degree of continuity of the till versus the sand because the permeability contrasts between the till and sand is so much greater than the variability among the different sands. (See paper by Graham Fogg in Water Resources Research, 22, 679.) Single-well tests would be useful for determing localized hydraulic conductivities of the sand bodies, not their connectivity.

Gathering existing data and constructing an initial vertical flow net proved useful in identifying data gaps in defining ground-water flow, and identified problems due to differing interpretations of the existing data. Determining options for gathering additional data necessary to resolve these issues was based on a qualitative understanding of the ground-water flow regime gleaned form construction of the vertical flow net.

References

Fogg, Graham. Water Resources Research 22, 679.

Heath. 1984. Ground Water Regions of the U.S. USGS Water Supply Paper No. 2242

U.S. EPA. 1986. Criteria for Identifying Areas of Vulnerable Hydrogeology, Appendix B: Ground-Water Flow Net/Flow Line Construction and Analysis. Office of Solid Waste. Washington, D.C. 20460.

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CASE STUDY 29: USE OF DISPERSION ZONE CONCEPTS IN THE DESIGN OF A SURFACE WATER MONITORING PROGRAM

Point Illustrated

- Estimation of the dispersion zone of contaminants downstream of a release point can be used to help design a surface water monitoring program.

Introduction

When a contaminant is initially released to a body of water, the concentration of the contaminant will vary spatially until fully dispersed. In streams, the contaminant will disperse with the surrounding ambient water as the water moves downstream and will eventially become fully dispersed within the stream. Downstream from this point, the contaminant concentration will remain constant throughout the stream cross-section, assuming that streamflow is constant and that the contaminant is conservative (e.g., nondegradable). The area in which a contaminant's concentration will vary until fully dispersed, referred to here as the dispersion zone, should be considered when determining the number and location of sampling stations downstream from the release point.

Facility Description

A facility that processed zinc, copper and precious metals from ores operated along a stream for five years. The plant was closed after being cited for repeated fish kills, reportedly due to failures of a tailings pond dike. At present, the site is covered with tailings containing high concentrations of copper, zinc, cadmium, arsenic, and lead. There is no longer a tailings pond. This is the same facility described in Case Study Number 10.

Site Setting

The site is located on coarse colluvium (hill-slope deposits of weathered bedrock) and fine-grained alluvium. These deposits are typically 50-feet thick.

Metamorphic rock (phyllite) underlies the unconsolidated materials. Ground water moves laterally in the gravel formations from the steep valley walls toward the stream.

The site is located about 400 feet from the stream. Two drainage ditches cross the lower portion of the site and merge prior to leaving the site. The ditch carries the combined flow and discharges directly into the stream (Figure 1). No other tributaries enter the stream within 2 miles of this location. Downstream from the release point, stream width and depth remain fairly constant at 45 and 3 feet, respectively. Mean stream velocity is 0.5 feet per second and channel slope is .0005 feet per foot.

Sampling Program

A surface water monitoring program was designed as part of a Phase I investigation to determine the extent of contamination in the stream. Existing data from previous sampling had shown high concentrations of metals in the drainage ditch sediments (e.g., 5,170 mg/kg Cu and 11,500 mg/kg Zn). Ground-water data from the plant's well showed measurable concentrations of Cu (7 µg/ℓ) and Zn (54 µg/ℓ). The ground-water concentrations were only slightly above the Water Quality Criteria for aquatic life (5.6 µg/ℓ for Cu and 47 µg/ℓ for Zn, U.S. EPA, 1976). These differences are within the limits of analytical error. The contribution of metals to the stream by ground-water discharge was considered to be negligible.

Based on a review of the plant history and the available water quality and sediment data, a monitoring program was designed. The potential pathways by which metals could reach the stream appeared to be direct discharge from the drainage ditch, discharge of contaminated ground water, and storm water runoff over the general facility area. Plant records indicated that typical flows in the drainage ditch at its confluence with the stream varied from 1 to 3 cubic feet per second (cfs) in the Spring. During extreme flood conditions, the flow in the ditch exceeded 20 cfs. In the Summer, flows in the drainage ditches at all locations were

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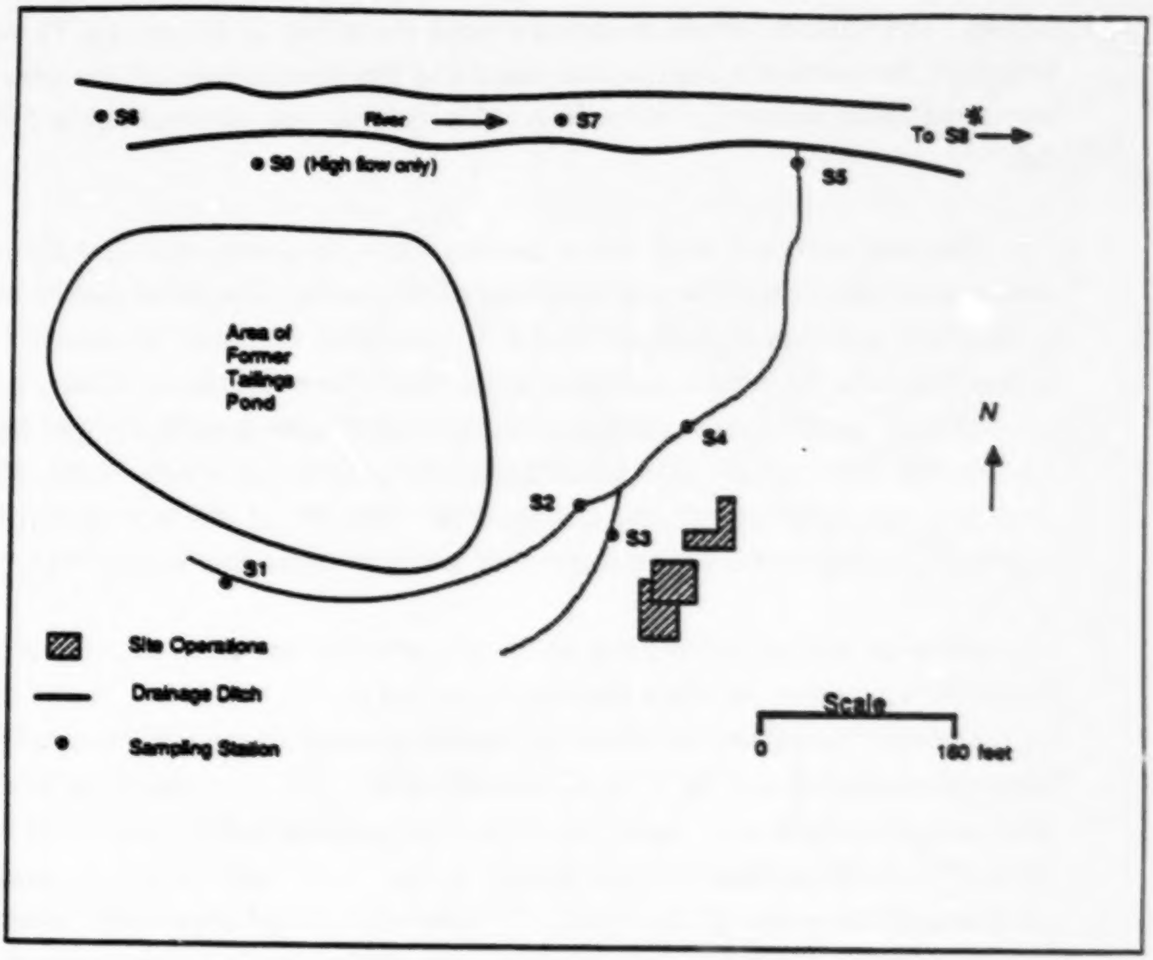
S6
River
S7
To S8*
S9 (High flow only)
S5
Area of Former Tailings Pond
S4
N
S2
S3
S1
Site Operations
Drainage Ditch
Sampling Station
Scale
0
100 feet

Figure 1. Sampling Station Locations for Surface Water Monitoring

* Located approximately 1030 feet downstream of the confluence of the ditch with the stream.

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less than 0.5 cfs. Resuspension of contaminated sediments in the ditches during storm runoff appeared to be the most likely pathway for metals to reach the stream. The specific metals of concern were identified as As, Cd, Cu, Pb and Zn, based on the processes used at the plant and the composition of the ores which contained some arsenopyrites (with As, Cu), galena (Pb), and sphalerite (with Zn, Cd).

The available soil and water quality data from previous sampling were reviewed to help determine the likely fate of the metals. The pH of soils in the area is about 6.5 and they contain about 0.5 percent organic matter by weight. Under such conditions, the metals, particularly Pb, would be expected to adsorb onto the soil particles. In the on-site tailings piles, the pH of core samples ranged between 3.3 and 4.9. Low soil pH values had been measured in sediments in the drainage ditch just downgradient of the tailings pile. The pH of the stream during the previous sampling was 6.9. The suspended solids concentration was 10 mg/l.

Estimates of the distribution of metals between the dissolved and adsorbed phases for a range of partition coefficients (K) are shown in Table 1. For example, if $K_p = 10^4$ and the suspended solids concentration was 10 mg/l, 90 percent (0.9) of the metal present would be in the dissolved phase. This information indicated that even though a metal (e.g., lead) was known to strongly sorb, a significant amount could still be transported in the dissolved phase. Thus, both water and suspended solids should be analyzed for metals. The complete list of parameters selected for measurement.in the Phase I investigation and the rationale for their selection are outlined in Table 2.

The sampling stations were selected to determine stream water quality up and downstream of the site and to determine whether particulates with sorbed metals were deposited on the stream banks or streambed. The sampling stations and the rationale for their selection are listed in Table 3. The station locations are shown in Figure 1. Because floods were considered to be one cause of contamination incidents, samples were to be collected under both high and low flow conditions.

The location of the downstream station (S8) was determined after estimating the stream length that may be required for complete dispersion of the contaminants. The following equation was used for this estimation:

Table 1

Relationship of Dissolved and Sorbed Phase Contaminant Concentrations to Partition Coefficient and Sediment Concentration

K_p	SS	C_W/C_T[a]
10^0	1	1.0
	10	1.0
	100	1.0
	1000	1.0
	10000	1.0
10^1	1	1.0
	10	1.0
	100	1.0
	1000	1.0
	10000	0.9
10^2	1	1.0
	10	1.0
	100	1.0
	1000	0.9
	10000	0.5
10^3	1	1.0
	10	1.0
	100	0.9
	1000	0.5
	10000	0.1
10^4	1	1.0
	10	0.9
	100	0.5
	1000	0.1
	10000	0.0

After Mills et al., 1985.

[a] The fraction dissolved (C_W/C_T) is calculated as follows:

$$\frac{C_W}{C_T} = \frac{1}{1 + K_p \times 5\times10^{-6}}$$

where K_p = partition coefficient, ℓ/kg
SS = suspended solids concentration, mg/ℓ
C_w = Dissolved concentration
C_T = Total concentration

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Table 2

Parameters Selected for Surface Water Monitoring Program

Parameters	Rationale
Metals - As, Cd, Cu, Pb, Zn	Determine extent of contamination
pH	Needed to predict sorption behavior, metal solubility, and speciation
Dissolved Oxygen, Sulfide, Fe(II), Fe(III)	Needed to determine redox conditions which influence behavior of metals, particularly the leaching of tailings
Alkalinity	A measure of how well buffered a water is, allows consideration of the likelihood of pH change
Total Dissolved Solids	Used as a water quality indicator and for QA/QC checks
Major Cations (Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, NH_4^{+}) and Major Anions (Cl^{-}, SO_4^{-2}, NO^{-}_{3})	May identify other waste sources, can influence fate of trace metals
Suspended Solids	Needed to predict the fraction of metal in water which is sorbed
Streamflow	Needed to compute mass balances and assist in identifying sources of observed contamination

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Table 3

Selected Surface Water Monitoring Stations and Selection Rationale

Station	Media	Rationale
Drainage ditch west of site (S1)	Water and sediments	Determine whether off-site drainage is significant source of contamination
Drainage ditches on site (S2 and S3)	Water and sediments	Identify on-site sources
Downstream of confluence of 2 ditches (S4)	Water and sediments	Provide information for checking mass balances from the 2 drainage ditches
Mouth of drainage ditch (S5)	Water, suspended sediment, bedload	Determine quality of direct discharge to stream
Stream (S6, S7 and S9)	Water, suspended sediment, bedload	Determine upstream water quality
Stream (S8)	Water, suspended sediment, bedload	Determine quality downstream of site following complete dispersion and provide data for mass balance

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$$DZ = \frac{0.4 w^2 u}{0.6 d \sqrt{gds}}$$

where:

DZ = dispersion zone length, ft
w = width of the water body, ft
u = stream velocity, ft/sec
d = stream depth, ft
s = slope (gradient) of stream channel, ft/ft
g = accerleration due to gravity (32 ft/sec^2).

Using the above equation, the estimated stream length required for complete contaminant dispersion is 1030 feet. This can serve as an approximate distance downstream from the release point at which a sampling station should be located.

Case Discussion

This case illustrates the use of contaminant dispersion zones in the design of a surface water monitoring program. In this example, the data indicate that approximately 1030 feet of flow within the described stream channel is required before a contaminant will become fully dispersed. A downstream station should therefore be located at or below this dispersion zone to fully characterize the extent of the release. An adequate number of sampling stations should also be located upstream from this point.

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CASE STUDY 30: EXAMPLE HEALTH AND SAFETY PLAN

The following health and safety plan was taken directly from the following EPA document.

U.S. EPA. 1983. Personnel Protection and safety. Office of Emergency and Remedial Response. Washington, D.C. 20460.

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APPENDIX IV

SITE SAFETY PLAN

I. INTRODUCTION

A site safety plan must be prepared (or reviewed) by a qualified safety person for each response involving hazardous substances. As soon as possible after operations at an incident commence, safety requirements must be written, conspicuously posted, distributed to all response personnel and discussed with them. In non-emergency situations, for example, remedial action at abandoned hazardous waste sites, safety plans can be developed simultaneously with general operation plans and implemented when remedial actions begin. Emergency situations may require verbal safety instructions and use of standard operating safety procedures until specific safety protocols can be written. For any incident, the plan must include health and safety considerations for all activities required at the incident. The safety plan must be periodically reviewed to keep it current and technically correct.

II. MINIMUM REQUIREMENTS

As a minimum, the site safety plan must:

- Evaluate the risks associated with the incident and with each operation conducted.
- Identify key personnel and alternates responsible for both site safety and response operations.
- Address Levels of Protection to be worn by personnel during various site operations.
- Designate work areas (exclusion zone, contamination reduction zone, and support zone), boundaries, size of zones, distance between zones, and access control points into each zone.
- Establish decontamination procedures for personnel and equipment.
- Determine the number of personnel and equipment needed in the work zones during initial entries and/or subsequent operations.
- Establish site emergency procedures, for example, escape routes, signals for evacuating work parties, emergency communications (internal and external), procedures for fire and/or explosions, etc.
- Determine location and make arrangements with the nearest medical facility (and medical life squad unit) for emergency medical care for routine-type injuries and toxicological problems.

- Implement a program for periodic air, personnel monitoring, and environmental sampling.
- Train personnel for any non-routine site activities.
- Consider weather and other conditions which may affect the health and safety of personnel during site operations.
- Implement control procedures to prevent access to the site by unauthorized personnel.

PERSONNEL SAFETY PLAN

OTTATI AND GOSS
HAZARDOUS WASTE SITE

Kingston, New Hampshire

Third Revision
Revised: 19 May 1982

* This is a copy of an actual safety plan currently being used on the Ottati and Goss hazardous waste site. It is provided here only as an example of how a safety plan may be assembled. Some of the original contents have been omitted because they can be found elsewhere in the manual.

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I Purpose

The purpose of this plan is to assign responsibilities, establish personnel protection standards, mandatory operating procedures, and provide for contingencies that may arise while operations are being conducted at the Ottati and Goss Hazardous Waste Site in Kingston, New Hampshire.

II. Applicability

The provisions of the plan are mandatory for all EPA personnel and personnel under contract to EPA while Section 311 activities are being conducted at the site. These activities include investigation, sampling, and mitigation undertaken on the site or at any off-site areas which may be affected by contamination from the site. All visitors to the site will be required to abide by these procedures. It is strongly recommended that State of New Hampshire personnel involved in cooperative site operations implement these procedures.

III. Responsibilities

1. On-Scene Coordinator (OSC)

In accordance with 40 CFR 1510.36: "The OSC shall direct Federal pollution control efforts and coordinate all other Federal efforts at the scene of a discharge or potential discharge."

A. At the Ottati & Goss site, the OSC has the primary responsibility for:

1. Assuring that appropriate personnel protective equipment is available and properly utilized by all EPA and contractor personnel.

2. Assuring that personnel are aware of the provisions of this plan, are instructed in the work practices necessary to ensure safety, and in planned procedures for dealing with emergencies.

3. Assuring that personnel are aware of the potential hazards associated with site operations.

4. Supervising the monitoring of safety performance by all personnel to ensure that required work practices are employed.

5. Correcting any work practices or conditions that may result in injury to personnel or exposure to hazardous substances.

B. The On-Scene Coordinator for this site is: Robert Ankstitus.

2. Safety Officer

In accordance with the draft chapter 9 of EPA's Occupational Health and Safety Manual, as ordered by Executive Order 12196: "The Safety Officer is responsible for implementing the safety plan at the site."

A. At the Ottati & Goss site, the Safety Officer shall:

1. Conduct site monitoring of personnel hazards to determine the degree of hazard present.

2. Determine personnel protection levels and necessary clothing and equipment to ensure the safety of personnel.

3. Evaluate weather and chemical hazard information, and recommend to the OSC any necessary modifications to work plans and personnel protection levels to maintain personnel safety.

4. Monitor the safety performance of all personnel to ensure that the required practices are employed.

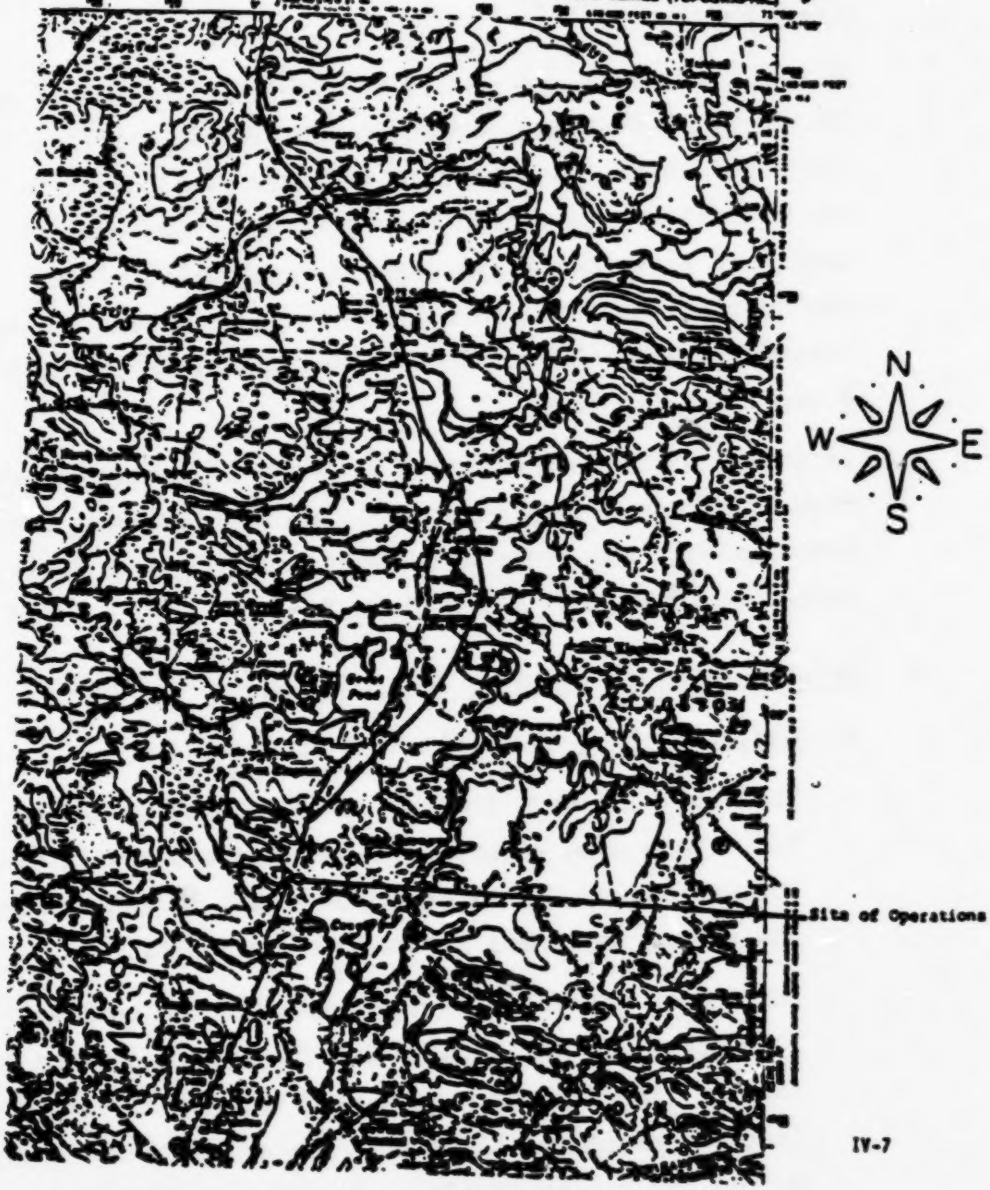
B. The Safety Officer for this site is: Gordon Bullard

IV. Site Organization

The Ottati & Goss Hazardous Waste Site is located in Kingston, New Hampshire near Rte. 125 (See Map, Figure 1). The site is part of a borrow pit operati

Ottati & Goss Hazardous Waste Site Kingston, NH

HAVERHILL QUADRANGLE
NEW HAMPSHIRE–MASSACHUSETTS
15 MINUTE SERIES (TOPOGRAPHIC)



Site of Operations

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adjacent to a small stream which flows via a marsh into Country Pond. Within 100 yards of the stream 4300 drums, in various stages of deterioration were abandoned. These open and sealed drums contain various hazardous substances. Some of these drums, due to their condition and displacement by rainfall, have contaminated the ground in the area where they were abandoned.

During the winter and spring and 1981, EPA undertook operations to move the drums into staging areas preparatory to sampling them. During the course of these operations an H-NU was used to obtain organic vapor levels for the site. The ambient air (including background) for the site usually indicated less than 5 ppm organic vapor with frequent increases to 20-30 ppm in the immediate vicinity of the drum movement operations. Some individual drums, checked on a random basis, indicated 2000+ ppm (within 6 inches of the bung).

In order to reduce the potential for contaminant migration and reduce the risk of personnel exposure to hazardous substances, three zones will be established. The three zones are: 1) Exclusion Zone; 2) Contamination Reduction Zone; and 3) The Clean Zone.

V. Determination of Zones of Contamination

A. Exclusion Zone (See Site Plan, Figure 2)

The Exclusion Zone is the area southerly of the small stream at point "H". This area encompasses the sand and gravel pit. Within this zone the designated "level of hazard" will be established, necessitating the use of personnel protection equipment.

Due to the condition of the drums and the soil and debris of the former drum storage site, a potential for wind migration of contaminants exists. The Exclusion Zone has, therefore, been made sufficiently large to encompass forseeable dispersion based on operations conducted during the spring of 1981. In order to facilitate operations in this zone, three sub-areas will be established:

1. "Area C" will be the area within the Exclusion Zone where only background vapor levels exist. This area serves as a buffer within

which wind dispersion of contaminants might occur. In "Area C" personnel will be required to wear the protective clothing designated for "Area B" operations and carry an air purifying respirator. A red flag will be flown in a prominent location to serve as a wind reference.

2. "Area B" is the area within which the wearing of both protective clothing and respiratory protection will be required due to the potential for contamination from the drums during work activities. This area is in fact four locations: 1) Staging Area 1; 2) Staging Area 2; 3) Staging Area 3; and 4) Staging Area 4 (including the former drum handling area.

   NOTE: Experience during the summer of 1981 indicates that outside the above areas the level of hazard is negligible, but when operations resume it may be necessary to form them into one area.

3. "Area A" is the term used to delineate "hot spots" within "Area B". A hot spot is a point at which the contaminant levels are, at least periodically, higher than the level of hazard indicated for "Area B" and require an increase in protection above that provided. These spots will be identified by an orange "bicycle pennant." Personnel working in these areas will wear the respiratory protection and safety clothing necessary for the special degree of hazard. Additionally, personnel will use any necessary monitoring devices and safety tools to complete their specific tasks in a safe manner.

   In order to provide an adequate Safety Zone the special level of hazard protection area will extend at least 50 feet from the pennant.

B. Contamination Reduction Zone

The Contamination Reduction Zone serves as a buffer between the Clean Zone and the Exclusion Zone. The zone incorporates the entire borrow pit area and a portion north of the small stream.

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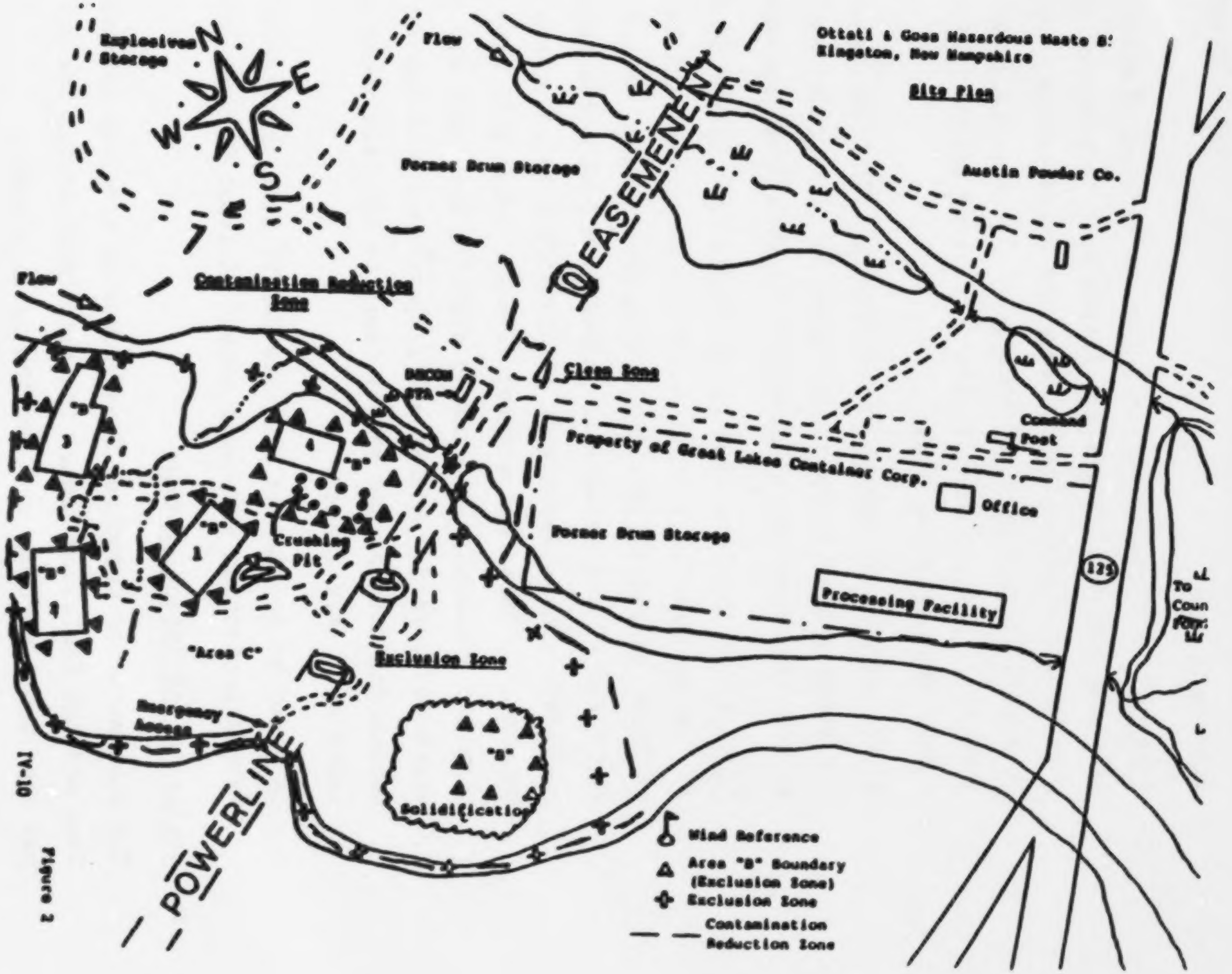
Ottati & Goss Hazardous Waste S:
Kingston, New Hampshire
Site Plan
Explosives Storage
N
E
S
W
Flow
Former Drum Storage
EASEMENT
Austin Powder Co.
Contamination Reduction Zone
Flow
Clean Zone
DECON STA.
Command Post
Property of Great Lakes Container Corp.
Office
"B"
3
4
"B"
"B"
1
"B"
2
Crushing Pit
Former Drum Storage
125
Processing Facility
To Coun Pow:
"Area C"
Exclusion Zone
Emergency Access
"B"
Solidification
POWERLIN
Wind Reference
Area "B" Boundary (Exclusion Zone)
Exclusion Zone
Contamination Reduction Zone

Figure 2

Personnel intending to enter the Exclusion Area shall don the appropriate protective clothing for the area(s) that they intend to enter, as well as, obtain the respiratory protective equipment that is necessary prior to crossing the Hotline at point "H" into the Exclusion Area.

Decontamination and Exclusion Zone equipment storage and maintenance will be carried out in this Zone. No equipment used in the Exclusion Zone will enter the Clean Zone until it has been decontaminated in the Contamination Reduction Zone. To support Exclusion Zone activities three facilities will be situated in the zone.

1. Decontamination Station

The Decontamination Station will be located at the other perimeter of the Contamination Reduction Zone. All personnel who have been within the Exclusion Area shall pass through a decontamination procedure prior to re-entering the Clean Zone (See Decontamination Procedure, Appendix I).

2. Heavy Equipment Park

A Heavy Equipment Park will be designated near the Decontamination Station for the storage, maintenance, and decontamination of vehicles used in the Exclusion Zone.

3. Weather Shelter

A Weather Shelter will be located in the Contamination Reduction Zone to provide some protection to personnel when taking breaks, without requiring them to fully decontaminate.

C. Clean Zone

The Clean Zone is the outer area and may be considered clear of contamination. The past history of the site, however, indicates that parts of this zone were used to stockpile drums prior to their being processed through a drum recycling facility owned by the Great Lake Container Corporation. Ground contamination is therefore present. Work that might be necessary in the former storage areas is to be considered to require protective clothing.

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Depending on the location, respiratory protection may not be necess

Private vehicles not needed for operations are restricted to the parking lot at the Command Post.

The EPA Command Post, or Mobile Laboratory, and an Equipment Trailer will be located within the Clean Zone.

1. The Command Post will serve as the OSC's headquarters and will be equipped with:
    a) First aid supplies
    b) Weather Station
    c) Communications
    d) Safety Plans
    e) Communication Watch
2. The Mobile Laboratory will be equipped to analyze and categorize the materials at the site. Access will be restricted in order to minimize contamination and interference with analysis.
3. The Equipment Trailer will be used to store safety materials pri— to their distribution from the clean side of the Decontamination Station. Other equipment will be stocked here for future use and damaged equipment will be repaired here after decontamination.

VI. Determination of the Level of Hazard

The level of hazard will be determined by periodic monitoring of the site for contamination by the Safety Officer (See Attachment 1).

The investigation, to date, has not indicated the presence of substances which may be absorbed through the skin. The investigation indicates that various substances, primarily industrial solvents, are present in sufficient quantities to cause irritation to the eyes, lungs, intestinal tract, and many are known or suspect carcinogens. Only a small portion of the drums have been sampled; therefore, personnel will be required to wear as a minimum:

A. Gloves

A 2-glove system will be worn.

1. Inner Gloves - Nitrile or PVC
2. Outer Gloves - Butyl Rubber or Nitrile

The inner gloves will be worn at all times within the Exclusion Zone. The outer gloves will be work when contact with drums and other contaminated materials is expected.

B. Disposable Splash Suit

All personnel, as a minimum, within the Exclusion Zone will wear a polylaminated Tyvek disposable coverall.

C. Head Gear

Hard hats will be worn at the site if overhead work occurs.

D. Eye Protection

Face shields or goggles will be worn within the Exclusion Zone. "Safety" glasses are not sufficient protection and contact lenses will not be worn at the site.

E. Boots

Cover boots will be worn in the Exclusion Area. Steel-toed boots will be worn by personnel handling drums, or coverboots over steel-toed workshoes.

F. Respiratory Protection

The respiratory protective devices used at this site will fall into three categories:

1. Positive Pressure, Demand, Open Circuit, Self Contained Breathing Apparatus (SCBA or Positive Pressure Demand Airline Respirator)
2. Air Purifying Respirator
3. Constant Flow

Only NIOSH/MSHA approved equipment will be used.

The level of respiratory protection to be used will be based upon the use of a photoionization detector (HNU). In order to provide a maximum of protection, the following procedure will be followed:

1. Positive pressure, demand, open circuit, SCBA will be worn if th level of organic vapors exceeds 25 ppm.
2. An air purifying respirator will be used when the organic vapor level is between 6 ppm and 25 ppm.
3. If the organic vapor level is 5 ppm or less, no device is necessary, but either an air purifying respirator or approved escape device will be carried.

Examples of NIOSH/MSHA approved devices are:

1. SCBA - MSA 401 Pressure Demand TC 13F-30
2. Air Purifying - MSA Ultra Twin Cartridge TC 21C-188 (cartridges and/or cannisters must be NIOSH approved for the respirator.)
3. Escape - Robertshaw 5-minute TC 13F-28

*PPM in Breathing Zone	Wear
0-5	None
6-25	Air Purifying
26+	S.C.B.A.

CAUTION: Individual jobs at the site may require personnel to wear an increased level of protection than generally necessary for the site. For example: 1) acid raingear; 2) butyl rubber aprons; 3) SCBA when others on air purifying respirator; and 4) hard hats with faceshields.

Note: Operations will be conducted during the summer months when excessive ambient air temperatures may cause personal injury and increased accident probability. Safety procedures to avoid heat stress casualty potential are outlined in Appendix XI.

*H-NU calibrated to 9.8 with benzene.

VII. Air Monitoring Survey

The Safety Officer will survey the site every second hour, and at such other times as deemed necessary by an alteration of wind speed or directi or the type of work being conducted, using a photoionization detector.

The Safety Officer shall use a copy of the Site Plan to indicate the location where readings were recorded, velocity of the wind, and the HNU reading. A minimum of 10 locations will be checked during each bihourly survey.

Three activated charcoal filter pumps will be maintained in the Contamination Reduction Zone and sampled twice a day in order to assess the composition of the organic vapors upwind, downwind, and within the Exclusion Zone.

VIII. Emergency Contingency Plan

On-site emergencies can be expected to result from fire, chemical reaction of drum contents or personnel casualty. If an incident occurs necessitating a response to an emergency, the OSC will sound an air horn. The signal is at least 5 short blasts (each of 1 second duration).

Personnel will assemble at the Decontamination Station to receive SCBA, orders to evacuate, or other assignments.

If the weather deteriorates to the point where the OSC believes work should cease, he will sound 1 prolonged blast (1 of 4-6 second duration) to order the crew to cease operations and assemble at the Decontamination Station.

Fire

If a fire emergency occurs the crew will assemble at the Decontamination Station, on the 5 blast signal. The OSC will issue his response orders, having already alerted the Fire Department (642-5512) and the Police Department (772-4716) to execute the Town Emergency Plan (See Appendix II). Fire fighting materials on-site will include:

1. 20 gallons of A Triple F foam,
2. 2 large dry chemical extinguishers (mounted on wheels)
3. 5 20-lb. dry chemical extinguishers
4. 4 MSA 401 SCBAs (for F.D. use only - additional to all others).

Drum Leak

Personnel will assemble at the Decontamination Station, on the 5 blast signal. The OSC will issue his cleanup orders, in order that the problem may be controlled and cleaned up rapidly. In addition to materials on-site for the job, the following materials will be on-site:

Lime - 200 lb.
Speedy Dry - 200 lb.
Overpack Drums - 100
Lab Packs - 25
Reconditioned Hazmat Drums - 100

Personnel Casualty

Personnel will assemble at the Decontamination Station, on the 5 blast signal, except for one man who will remain with the casualty. The OSC will issue orders for first aid assistance to the casualty. If the casualty has sustained an injury which may involve contact with contaminated material, a sample of the material will be taken for immediate analysis.

Severe Casualties

The OSC will contact the Kingston Ambulance (642-5512) for assistance. If the casualty requires transfer to a hospital, the primary hospital will be the Exeter Hospital. The OSC will contact the hospital (778-7311) and inform them of the incident and the nature of the injury. If Exeter Hospital is unable to assist (due to other emergencies), the OSC will contact Hale Hospital in Haverhill (372-7141) and alert them.

EMERGENCY TELEPHONE NUMBERS

Immediate Emergencies

1.	Kingston Police Dept.	(603) 772-4716
2.	Kingston Fire Dept.	(603) 642-5512
3.	Kingston Ambulance	(603) 642-5512

State your name, location, and the nature of the emergency.

Emergency Support

1. U.S. EPA (617) 223-7265
2. Peabody Clean Industry (617) 567-6500
3. Exeter Hospital (603) 778-7311 (7 digits only)

   Directions:

   A. North on Rte. 125 to Rte. 111
   B. East on Rte. 111 to Exeter Town Hall
   C. Turn right
   D. Follow Rte. 108 to hospital entrance on Highland St. (See Maps, Figures 3 & 4).

4. Hale Hospital, Haverhill, MA (617) 372-7141 (7 digits only)

   Directions:

   A. South on Rte. 125 to Haverhill's Central Plaza
   B. Turn left onto Ginty Blvd. (Rte. 97)
   C. Following Rte. 97 to Hale Hospital's entrance on Woodbridge Road (See Maps, Figures 3 & 5).

State Officials

1.	State Fire Marshall's Office	(603) 271-3336
2.	NHWSPCC	(603) 271-3503
3.	Bureau of Solid Waste Mgmt.	(603) 271-4611

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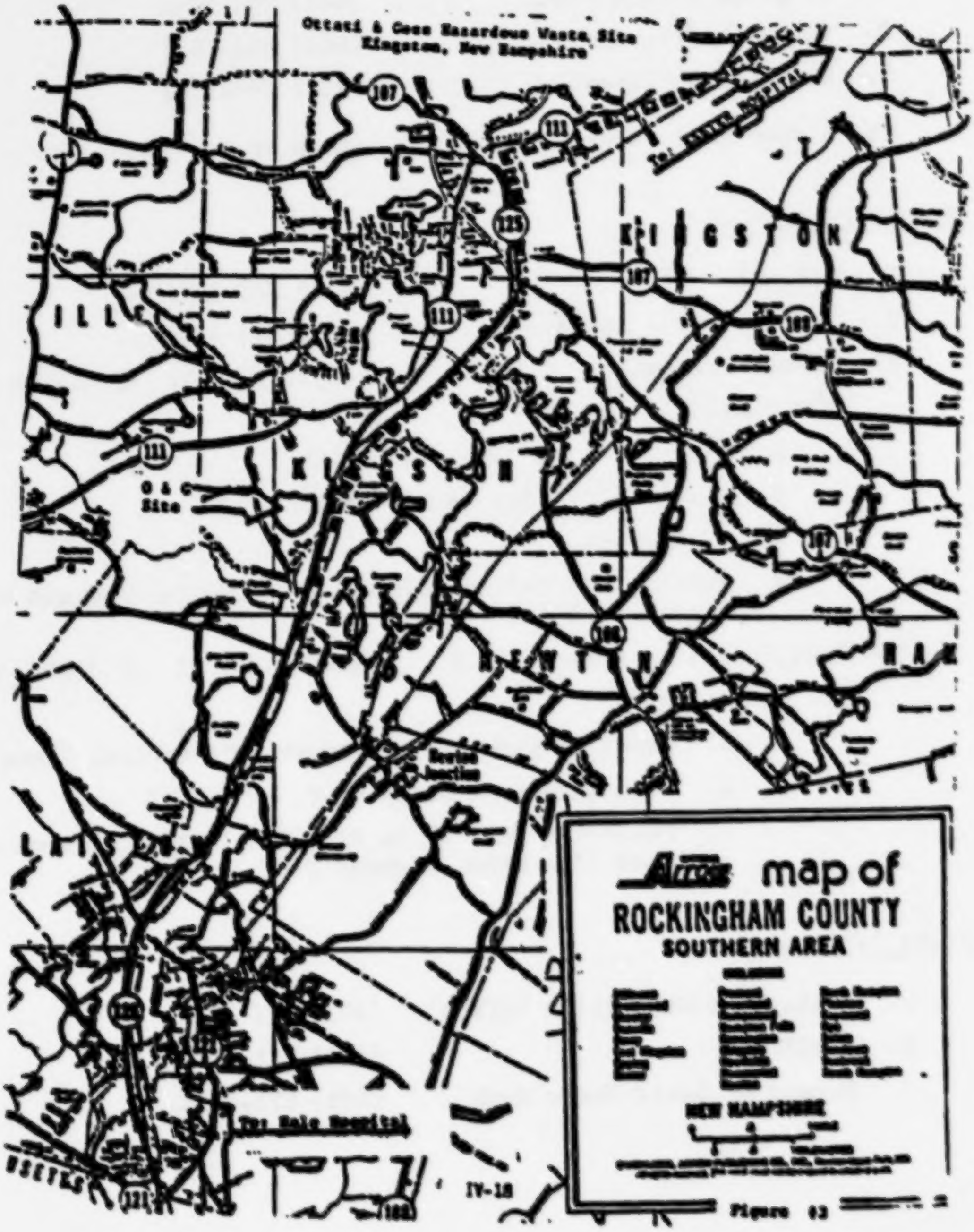
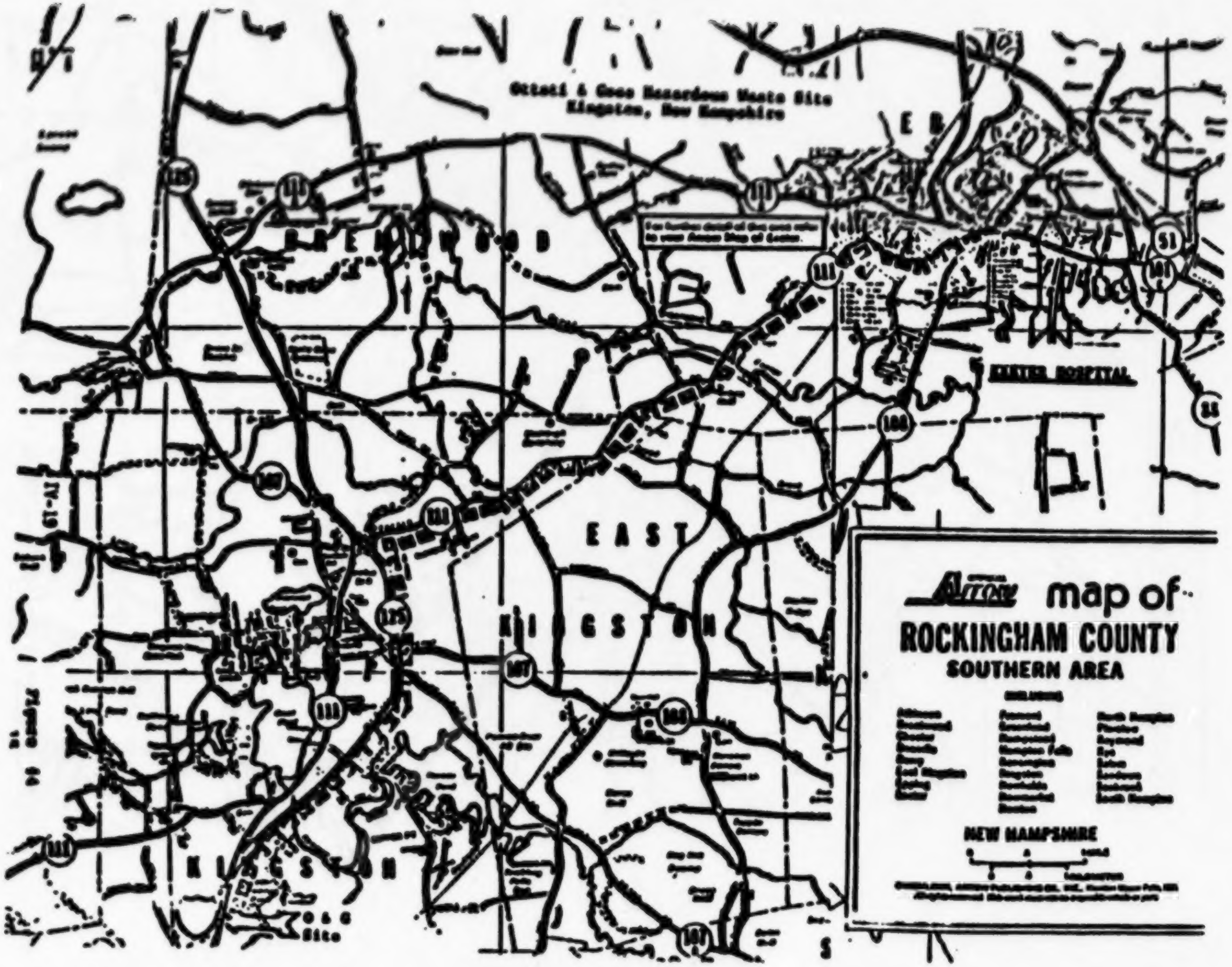

107
111
125
KINGSTON
107
111
108
ILL
111
O & G Site
KINGSTON
107
108
NEWTON
Newton Junction
125
121
108
To: Exeter Hospital
To: Hale Hospital
Arrow map of
ROCKINGHAM COUNTY
SOUTHERN AREA
NEW HAMPSHIRE

Ottati & Goss Hazardous Waste Site
Kingston, New Hampshire

Figure #3


Ottati & Goss Hazardous Waste Site
Kingston, New Hampshire
BRENTWOOD
EAST
KINGSTON
KINGSTON
EXETER HOSPITAL
Arrow map of
ROCKINGHAM COUNTY
SOUTHERN AREA
NEW HAMPSHIRE
O & G Site
IV-19
Figure 14
125
111
101
51
108
107
111A

IV-19

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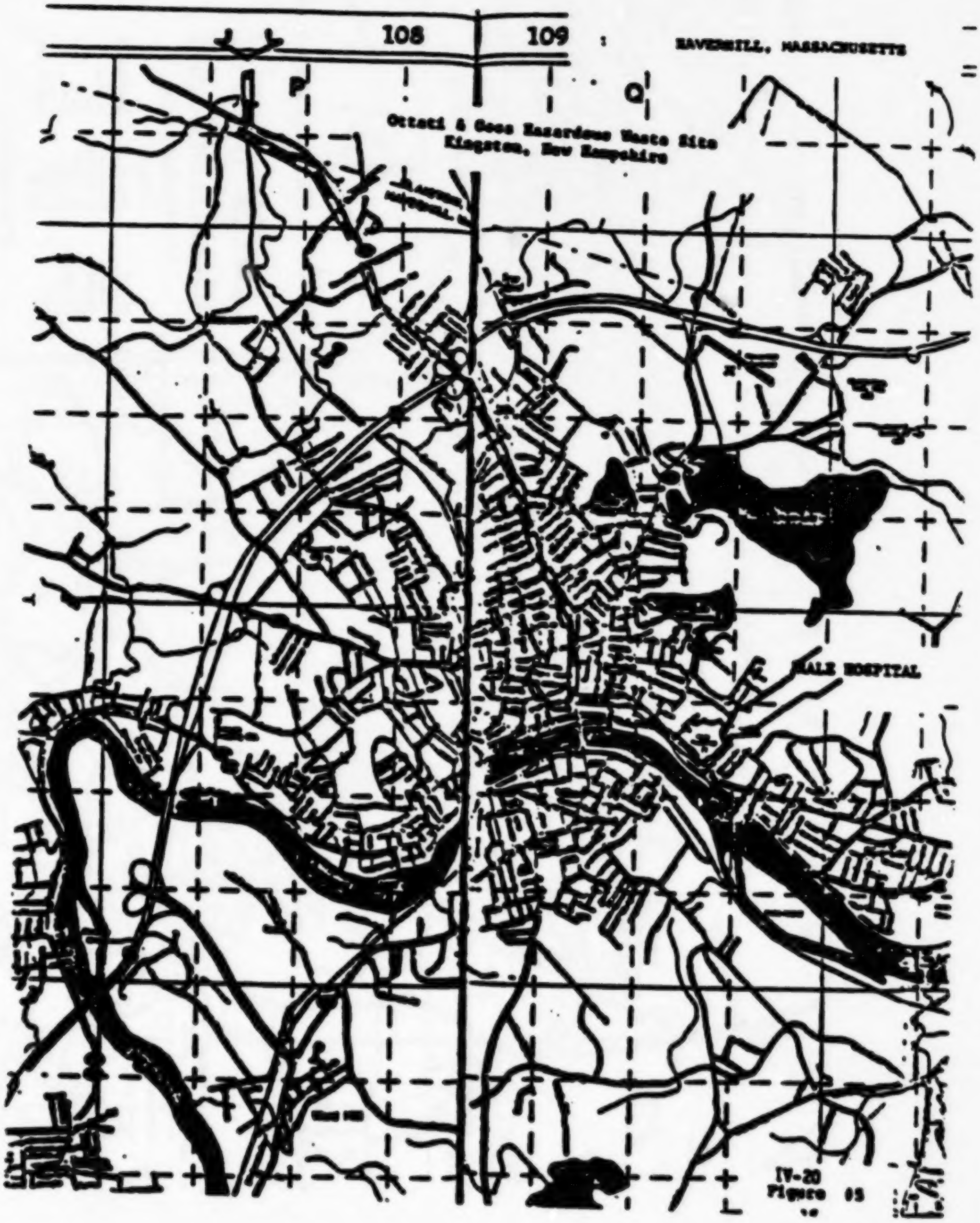

108
109
HAVERHILL, MASSACHUSETTS
P
Q
HALE HOSPITAL

Ottati & Goss Hazardous Waste Site
Kingston, New Hampshire

IV-20
Figure #5

DEGREES OF HAZARD
AND
LEVELS OF PERSONNEL PROTECTION

Degree of Hazard	Conditions	Level of Protection
First Degree	1. Unknown Hazards 2. IDLH Atmospheres 3. Oxygen Deficient Atmospheres	1. Self Contained Breathing Apparatus (SCBA) of the Positive Pressure Demand Type
	1. Unknown Hazards 2. Percutaneous Chemicals 3. Vapors which can injure the skin	2. Appropriate Type of Fully Encapsulating Suit.
Second Degree	1. IDLH Atmospheres 2. Oxygen Deficient Atmospheres	1. Self Contained Breathing Apparatus (SCBA) of the Positive Pressure Demand Type
	1. Liquids which can injure the skin	2. Boots, Gloves, Rain/Chemical Splash Suit with Hood.
Third Degree	1. Atmospheres with at least 19½% Oxygen 2. Atmospheres for which the Chemical & Concentration are Known and are below IDLH level. 3. Contaminants have Good Warning Properties	1. Approved Air Purifying Respirator (Gas Mask) with th Appropriate Approved Cartridg (Cannister) 2. Carry: Approved Emergency Escape Unit
	4. Atmospheres for which a NIOSH/MSHA approved Cartridge/Cannister is available	1. Boots, Gloves, ChemClos (Splas Suit if necessary), Face Shiel or goggles.
Fourth Degree	1. Atmospheres with at least 19½% oxygen 2. No IDLH Atmospheres 3. Dust and other particulates in the Air	1. Approved Air Purifying Respirator (Gas Mask) with the Appropriate Approved Cartridge (Cannister). 2. Carry: Approved Emergency Escape Unit
	1. No Harmful Chemicals or Atmospheres that might injure the skin	1. Boots, Gloves, Coveralls, Face Shield/Goggles
Fifth Degree	1. Atmosphere with at least 19½% Oxygen 2. Atmosphere which contains no Hazards-But where a Hazardous Substance Incident ight occur.	1. Carry: Approved Emergency Escape Unit 1. Appropriate Clothing for the investigation/inspection.

APPENDIX I

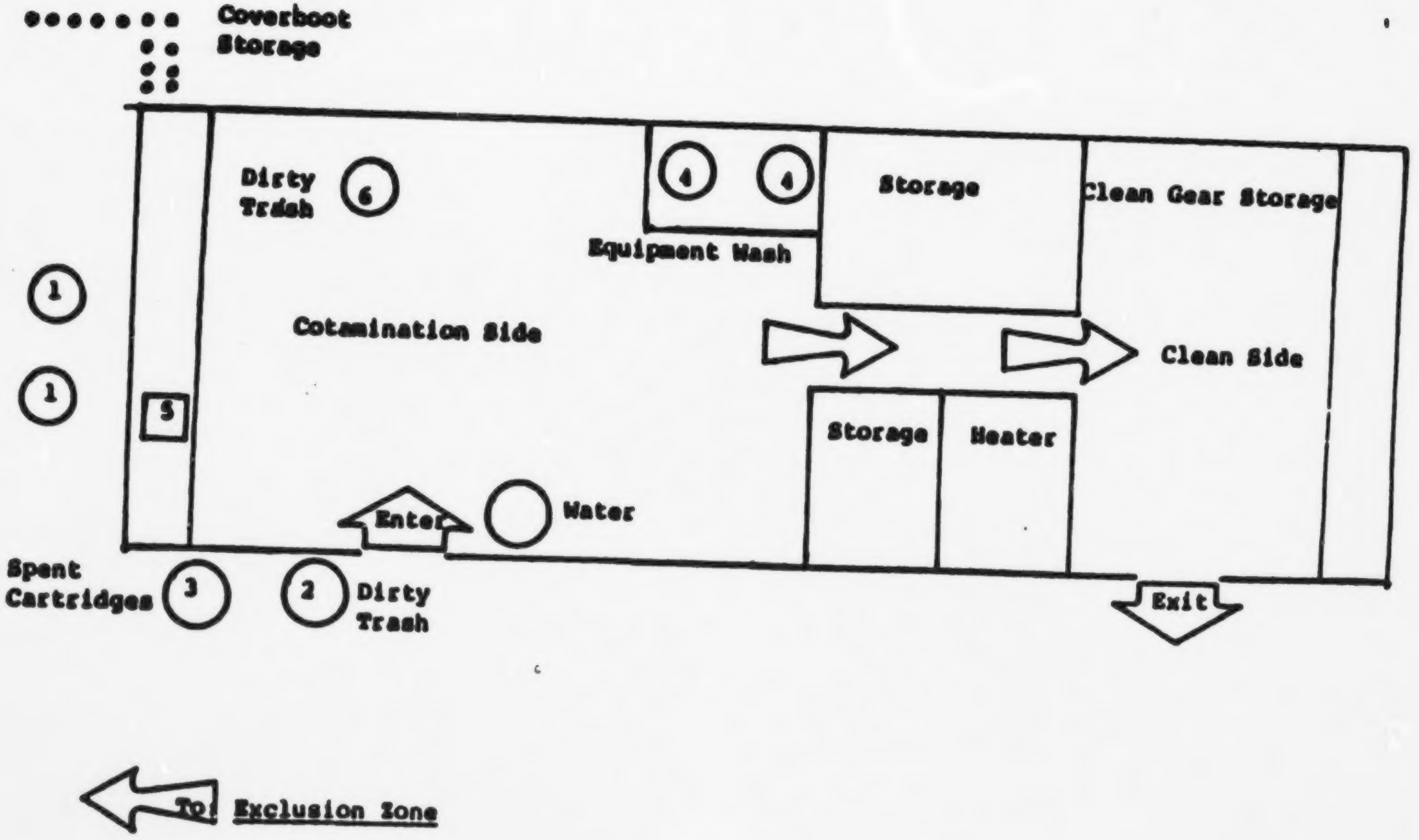
Decontamination Procedure

The Decontamination Procedure shall be used when contact with contaminants is made or when personnel depart the Standby Zone.

1. Personnel Scrub Boots at the Pans provided Outside the DECONSTA.
2. Disposable Tyvek Clothing and Gloves are Disposed of into the the Dirty Trash Drum provided outside the DECONSTA.
3. Spent Cartridges/Cannisters are disposed of into the Drum provided outside the DECONSTA.
4. The DECONSTA is entered for the Decontamination of other equipment in the pans provided in the DECONSTA.
5. Use a new set of inner gloves to clean equipment.
6. Dispose of any generated Dirty Trash in the Drum provided in the Contamination portion of the trailer.
7. Depart the DECONSTA via the Clean Room, for the issue of new clothing/material, or depart from the Standby Zone.

DECONTAMINATION PROCEDURE

Contamination Reduction Zone



Coverboot Storage
Dirty Trash
6
4
4
Equipment Wash
Storage
Clean Gear Storage
1
1
5
Cotamination Side
Clean Side
Storage
Heater
Enter
Water
Spent Cartridges
3
2
Dirty Trash
Exit
To: Exclusion Zone

CASE STUDY 31: USE OF HISTORICAL AERIAL PHOTOGRAPHS AND FACILITY MAPS TO IDENTIFY OLD WASTE DISPOSAL AREAS AND GROUND-WATER FLOW PATHS.

Points Illustrated

- Aerial photographs taken over many years in the life of a facility can be used to locate old solid waste management units (SWMUs).
- Historical aerial photographs can be used to identify geologic/topographic features that may affect ground-water flow paths.

Introduction

In gathering information pertaining to investigation of a release, historical aerial photographs and facility maps can be examined and compared to current aerial photographs and facility maps. Aerial photographs can be viewed as stereo pairs or individually. Stereo viewing, however, enhances the interpretation because vertical as well as horizontal spatial relationships can be observed. The vertical perspective aids in distinguishing various shapes, tones, textures, and colors within the study area.

Aerial photographs and facility maps can be used for the following:

- Providing evidence of possible buried drums. Historical photographs can show drums disposed of in certain areas where later photographs show no indications of such drums, but may show that the ground has been covered with fill material.
- Showing previous areal extent of landfill or waste management area. Earlier photos might show a much larger waste management area than later photographs.
- Showing areas that were dry but now are wet, or vice versa, indicating a possible release from an old waste management area.

- Showing changes in land use patterns (e.g., a landfill in an early photograph could now be a park or be covered by buildings).

- Soil discoloration, vegetation damage, or enhanced vegetative growth can sometimes be detected, indicating possible contaminant migration.

- Geologic/hydrologic information, such as faults, fracture or joint systems, old stream courses (channels), and the contact between moraines and outwash plains.

Facility description

This facility is the same as previously described in Case Studies 3, 4, 18 and 20.

Data collection and analysis

Over the past 50 years aerial photographs were taken of the facility area. Interpretation of the photographs produced important information that is shown diagramatically in Figure 1. Solid Waste Disposal Area 2 (SWDA-2) was lower in elevation in 1940 than it is now. In fact, the area appears to have been leveled and is now covered by vegetation, making it difficult to identify as a SWMU at ground level. Another area was identified as a possible waste disposal area from a historical review of photos. Further study of photos, facility maps and facility files revealed this to be a former Liquid Waste Disposal Area (LWDA), designated as LWDA-2 on Figure 1.

The use of these historical photographs also revealed geologic features that could affect the ground-water flow system under the facility. In this case, monitoring well data indicated a general northwesterly ground-water flow direction, in addition to a complex flow pattern near LWDA-1 and SWDA-1 (Figure 1). Recent photographs were analyzed, but because of construction and other nearby activities (e.g., cut and fill, sand and gravel mining), conclusions could not be

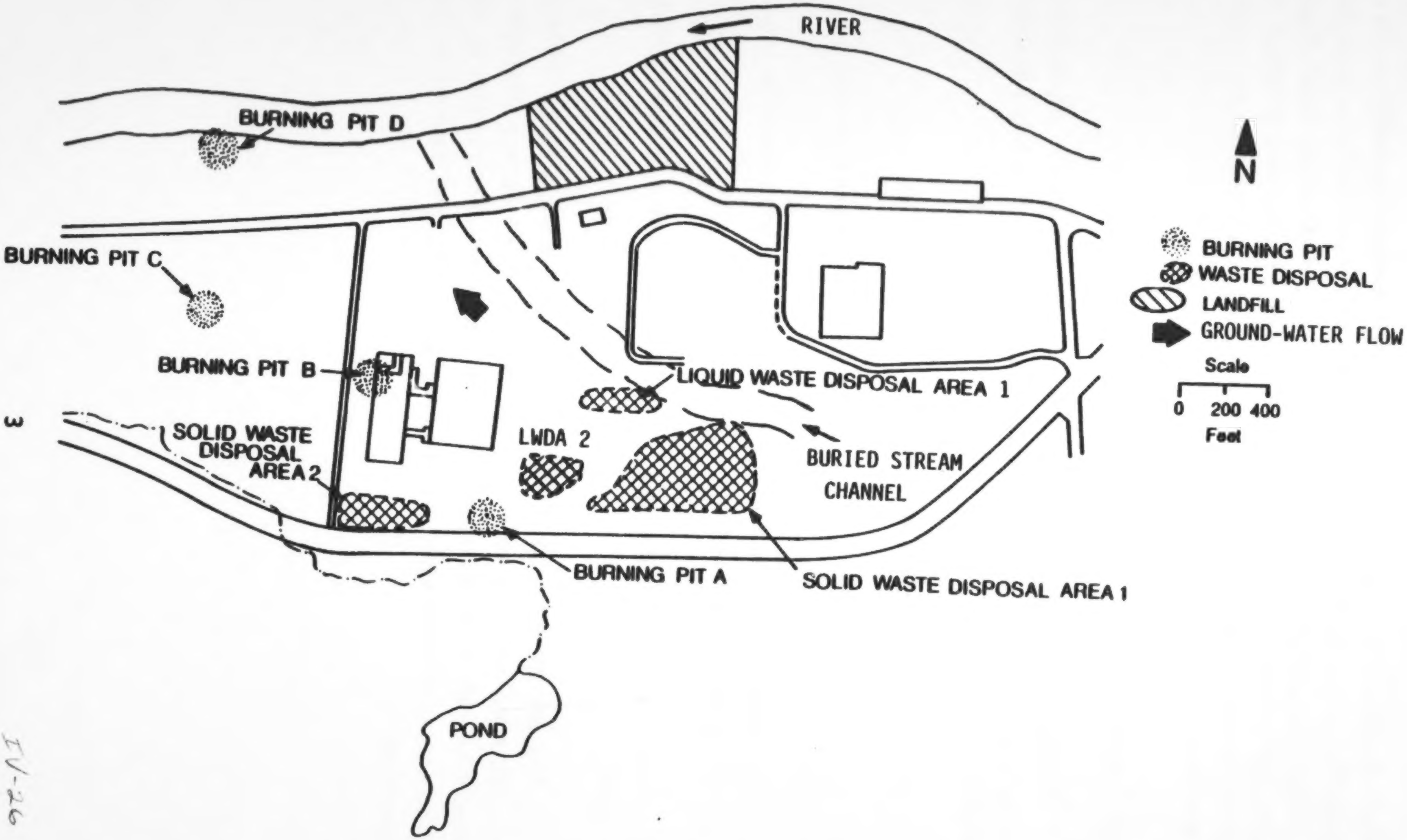

RIVER
BURNING PIT D
BURNING PIT C
BURNING PIT B
SOLID WASTE DISPOSAL AREA 2
LWDA 2
LIQUID WASTE DISPOSAL AREA 1
BURIED STREAM CHANNEL
BURNING PIT A
SOLID WASTE DISPOSAL AREA 1
POND
N
BURNING PIT
WASTE DISPOSAL
LANDFILL
GROUND-WATER FLOW
Scale
0 200 400
Feet

Figure 1 Site Layout. LWDA 2, SWDA 2 and Stream Channel Identified Through Use of Aerial Photo Analysis

IV-26

drawn. A review and analysis of old photographs revealed the existence of a buried stream channel of the river (Figure 1). This buried stream channel was identified as a preferential path for ground water and consequently contaminant migration. Additional monitoring data and further analysis of subsurface geologic data is needed to determine the full impact of the buried stream channel on the groundwater flow regime.

Case Discussion

Analysis and interpretation of a series of historical aerial photographs and facility maps spanning a period of over 50 years enabled facility investigators to identify the following:

(1) Location of waste disposal areas (e.g., old SWMUs);

(2) Changes in topography (related to earlier disposal activities); and

(3) Possible preferential pathways (e.g., old stream channel) for migration of ground water and contaminants.

This information was used to identify areas for more detailed sampling and analysis.

Analysis of historical facility maps and historical aerial photographic interpretation can be a very powerful tool in a RCRA Facility Investigation, but should be used in combination with other investigative techniques to result in a thorough characterization of the nature, extent, and rate of contaminant migration.